GIORGIO PARISI I EL DESCROBRIMENT D'UNA NOVA ORGANITZACIÓ DE LA MATÈRIA

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Cel.lebració del premi Nobel de Física 2021
IEC Barcelona, 23 Novembre 2021

The Nobel Prize in Physics 2021

Syukuro Manabe
Klaus Hasselmann
Giorgio Parisi

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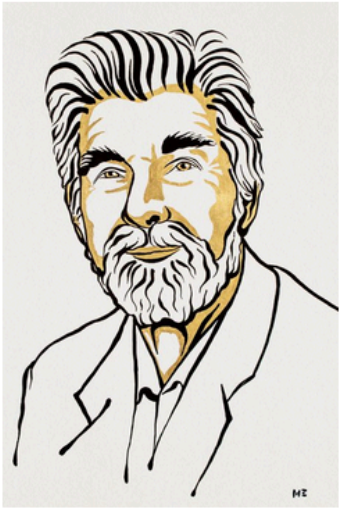
The Nobel Prize in Physics 2021

Ill. Niklas Elmehed © Nobel Prize Outreach

Syukuro Manabe

Prize share: 1/4



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Klaus Hasselmann

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Giorgio Parisi

Prize share: 1/2

The Nobel Prize in Physics 2021 was awarded "for groundbreaking contributions to our understanding of complex systems" with one half jointly to Syukuro Manabe and Klaus Hasselmann "for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming" and the other half to Giorgio Parisi "**for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales.**"

The Nobel Prize in Physics 2021

Syukuro Manabe
Klaus Hasselmann
Giorgio Parisi

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Giorgio Parisi
Facts

Giorgio Parisi
The Nobel Prize in Physics 2021

Born: 4 August 1948, Rome, Italy

Affiliation at the time of the award: Sapienza University of Rome, Rome, Italy

Prize motivation: "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales."

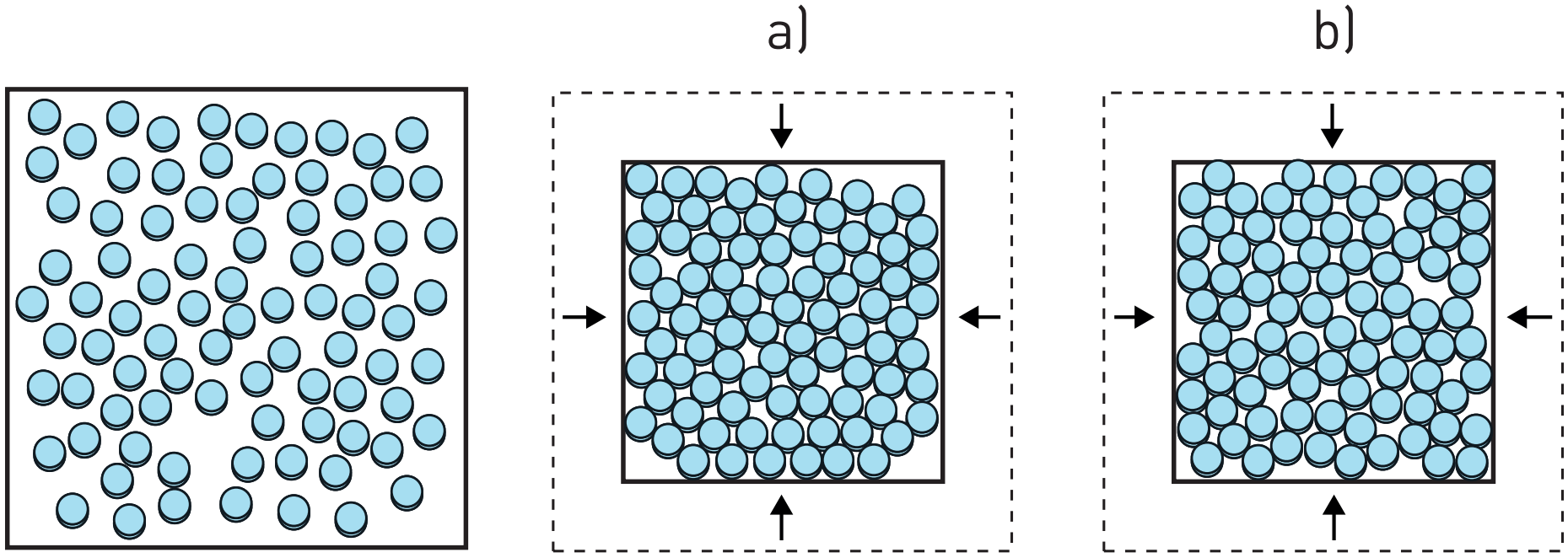
Prize share: 1/2

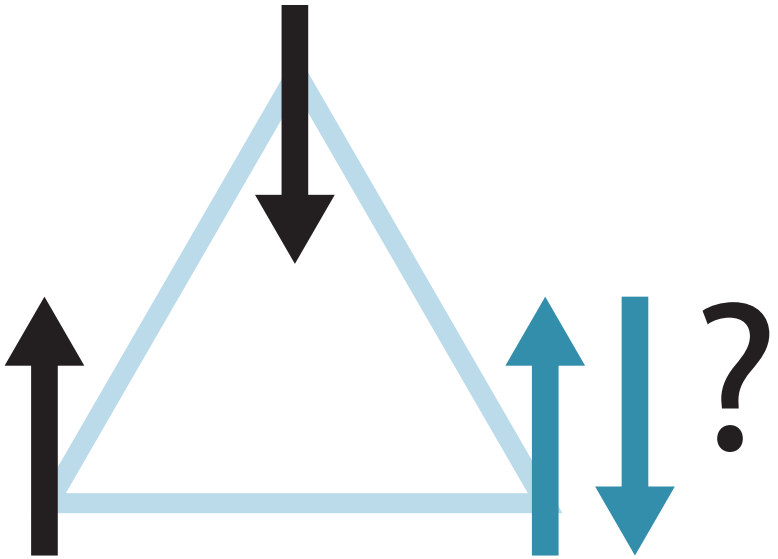
Around 1980, **Giorgio Parisi** discovered hidden patterns in disordered complex materials. His discoveries are among the most important contributions to the theory of complex systems. They make it possible to understand and describe many different and apparently entirely random materials and phenomena, not only in physics but also in other, very different areas, such as mathematics, biology, neuroscience and machine learning.

Les tres figures de la motivació del Nobel

Mathematics for complex disordered systems

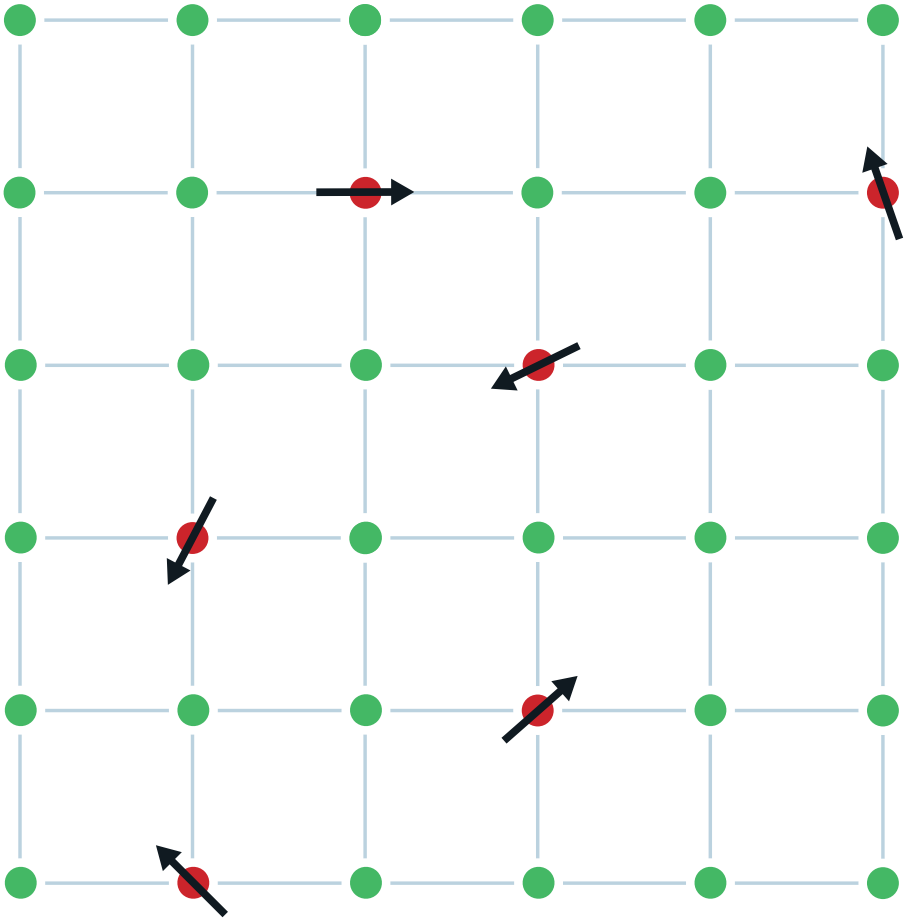
Every time many identical discs are squeezed together, a new irregular pattern is formed despite them being squeezed in exactly the same way. What governs the result? Giorgio Parisi discovered a hidden structure in such complex disordered systems, which these discs represent, and found a way of describing them mathematically.





Frustration

When one spin points upward and the other downward, the third one cannot satisfy them both at the same time, because neighbouring spins want to point in different directions. How do the spins find an optimal orientation? Giorgio Parisi is a master at answering these questions for many different materials and phenomena.



Spin glass

A spin glass is a metal alloy where iron atoms, for example, are randomly mixed into a grid of copper atoms. Each iron atom behaves like a small magnet, or spin, which is affected by the other magnets around it. However, in a spin glass they are frustrated and have difficulty choosing which direction to point. Using his studies of spin glass, Parisi developed a theory of disordered and random phenomena that covers many other complex systems.

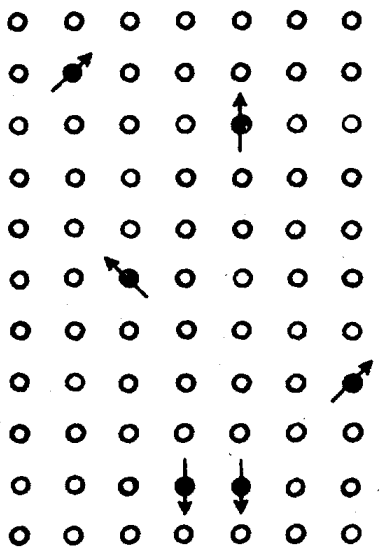
- Iron
- Copper

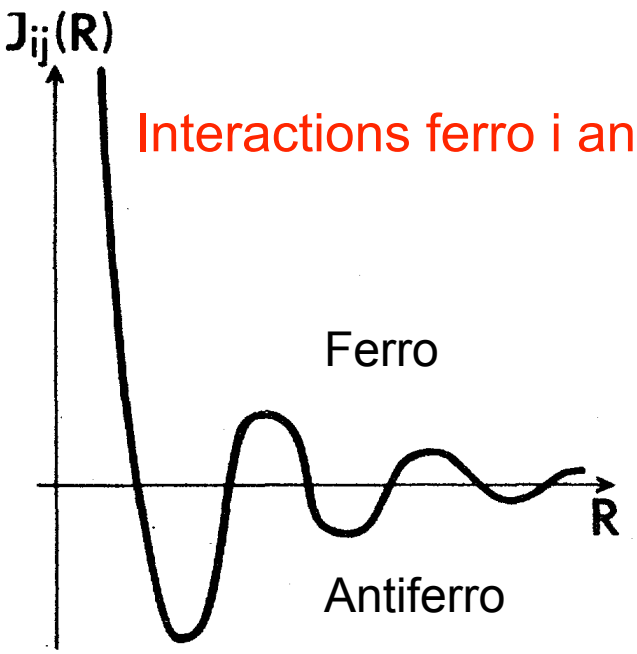
Una mica d'història….

Als anys 70 apareixen uns materials magnetics anomenats vidres d'espí (spin glasses)

Aliatge Cu(Mn13%)

Cu ○
Mn ●

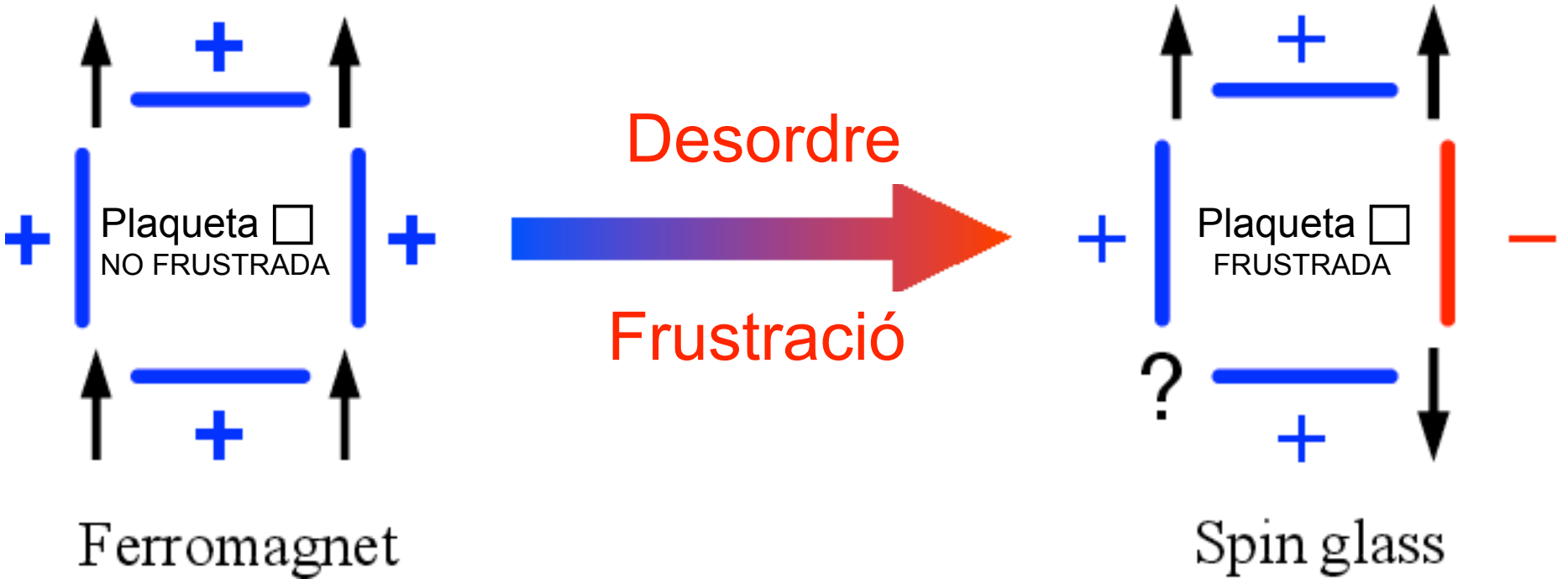




Interactions ferro i antiferromagnètiques

$$E_{ij} = -J_{ij} s_i s_j$$

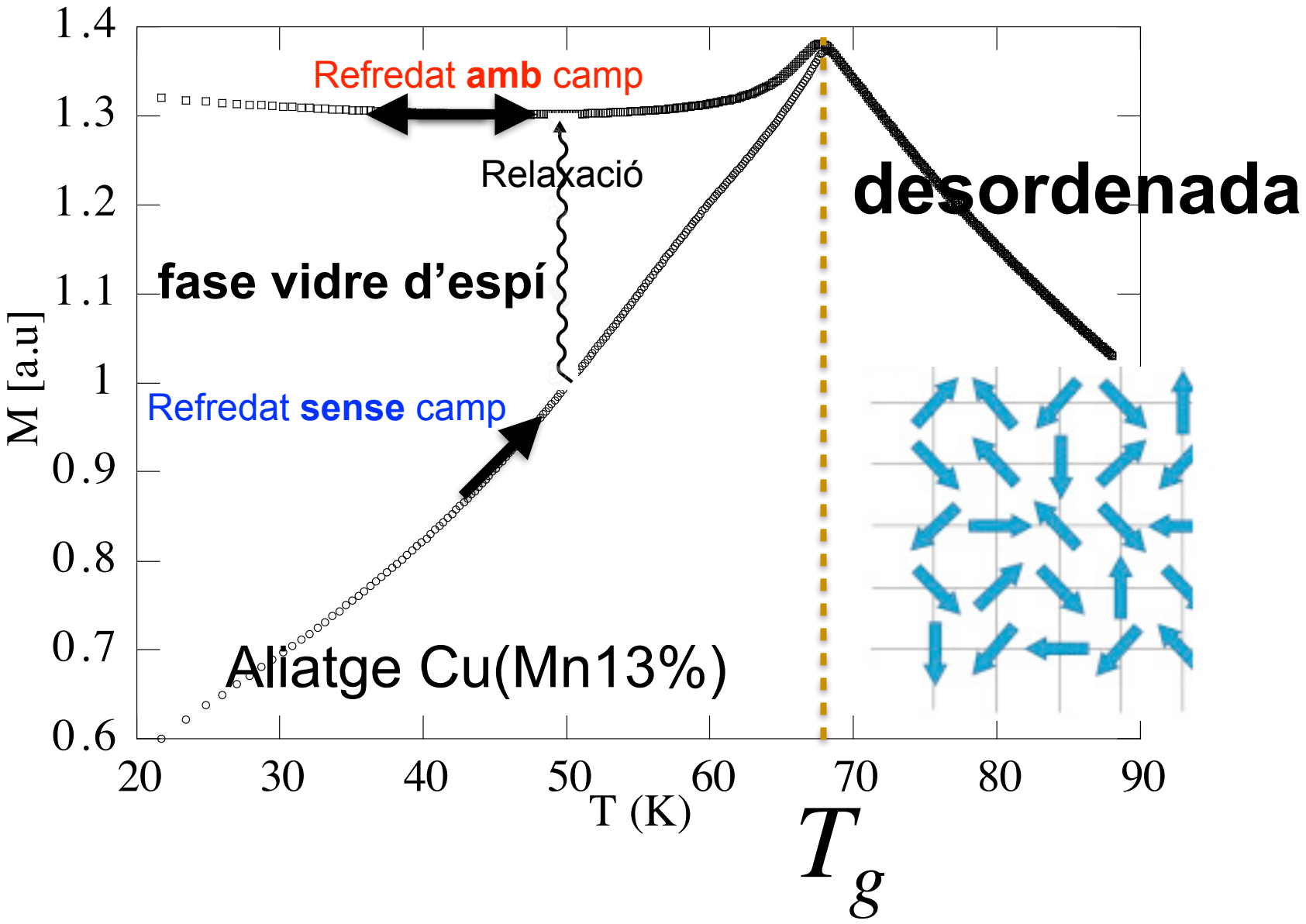
Desordre i frustració



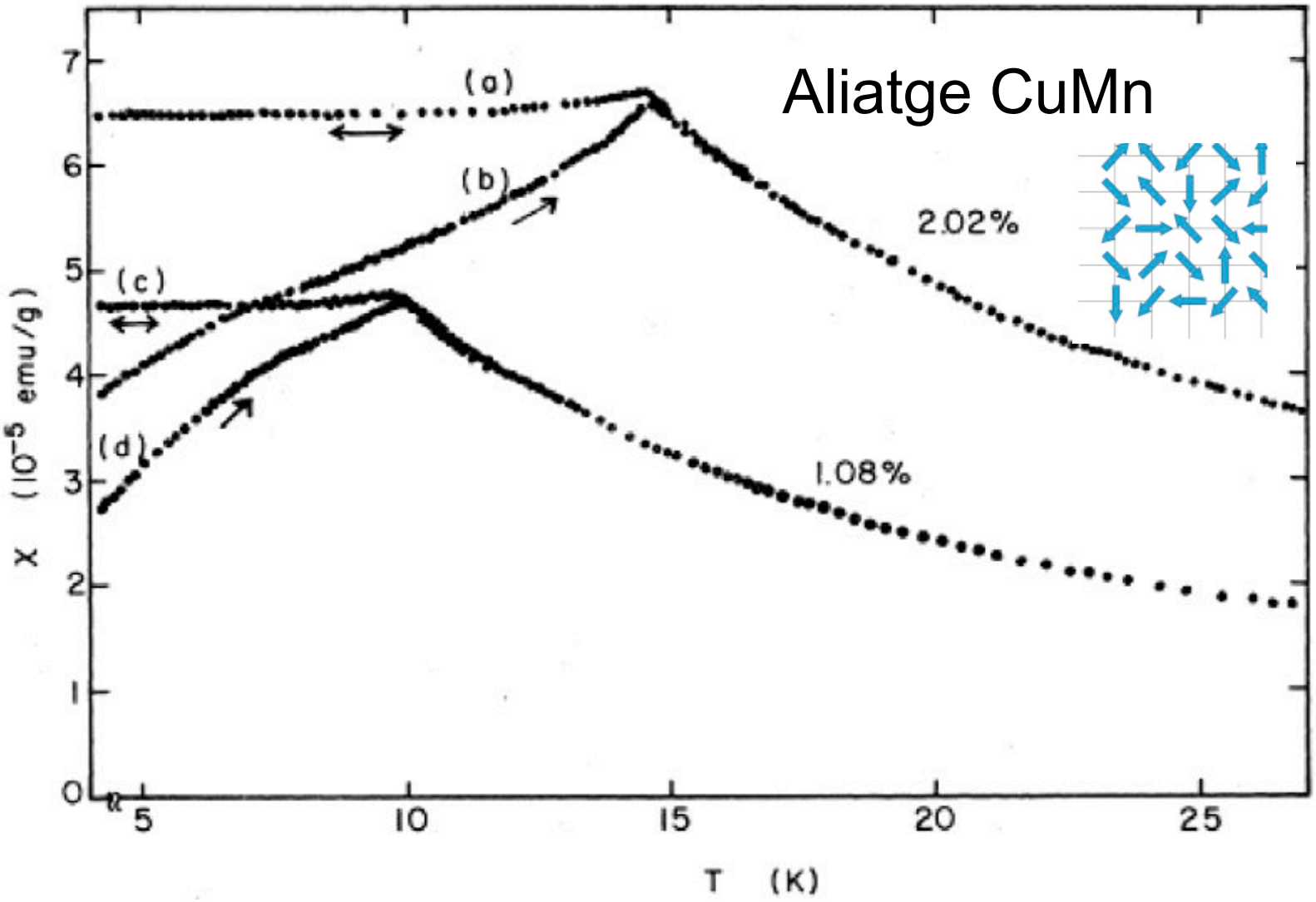
$$\prod_{i \in \square} J_i = +$$

$$\prod_{i \in \square} J_i = -$$

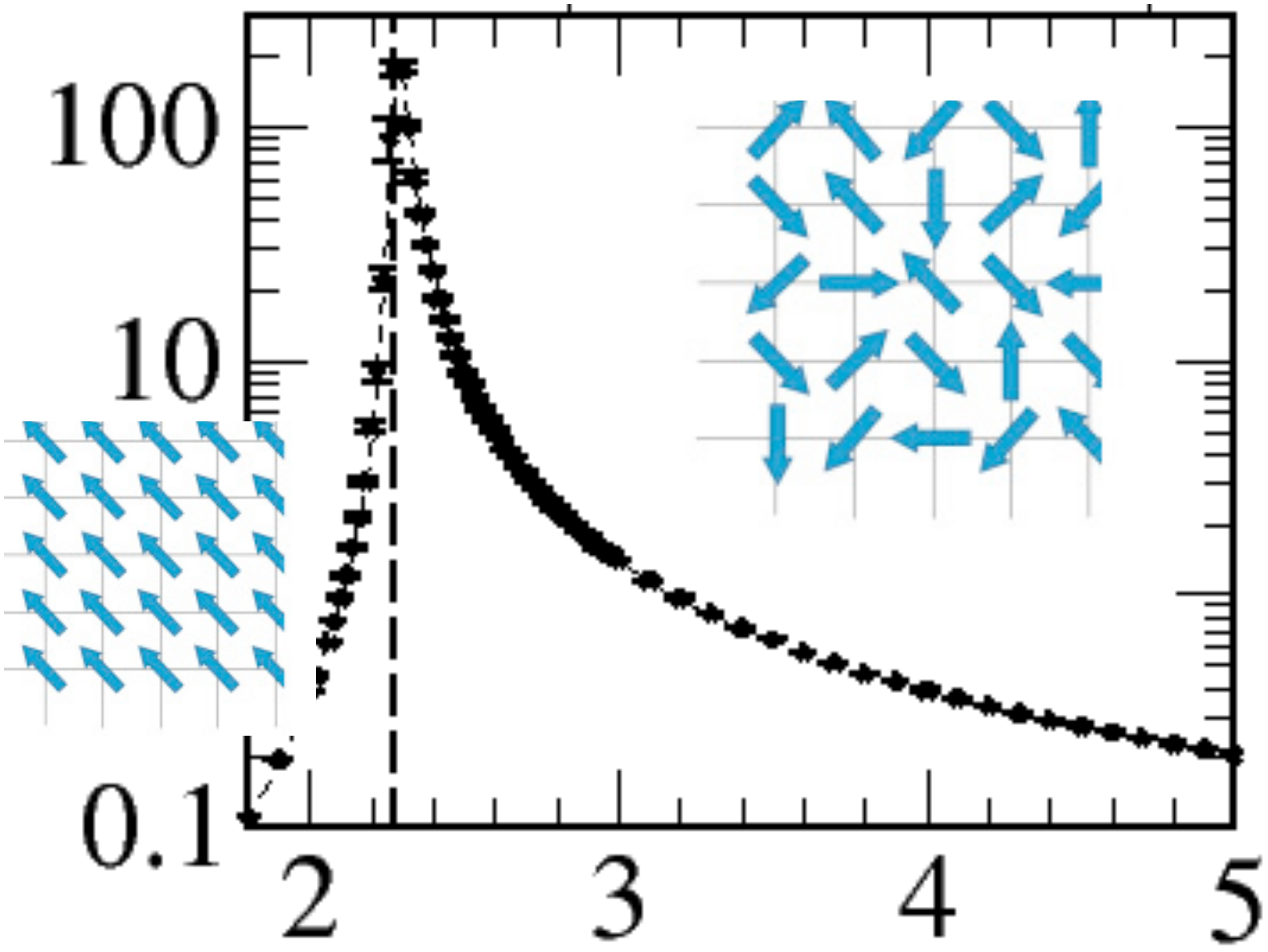
Transicio de fase i fenomens irreversibles



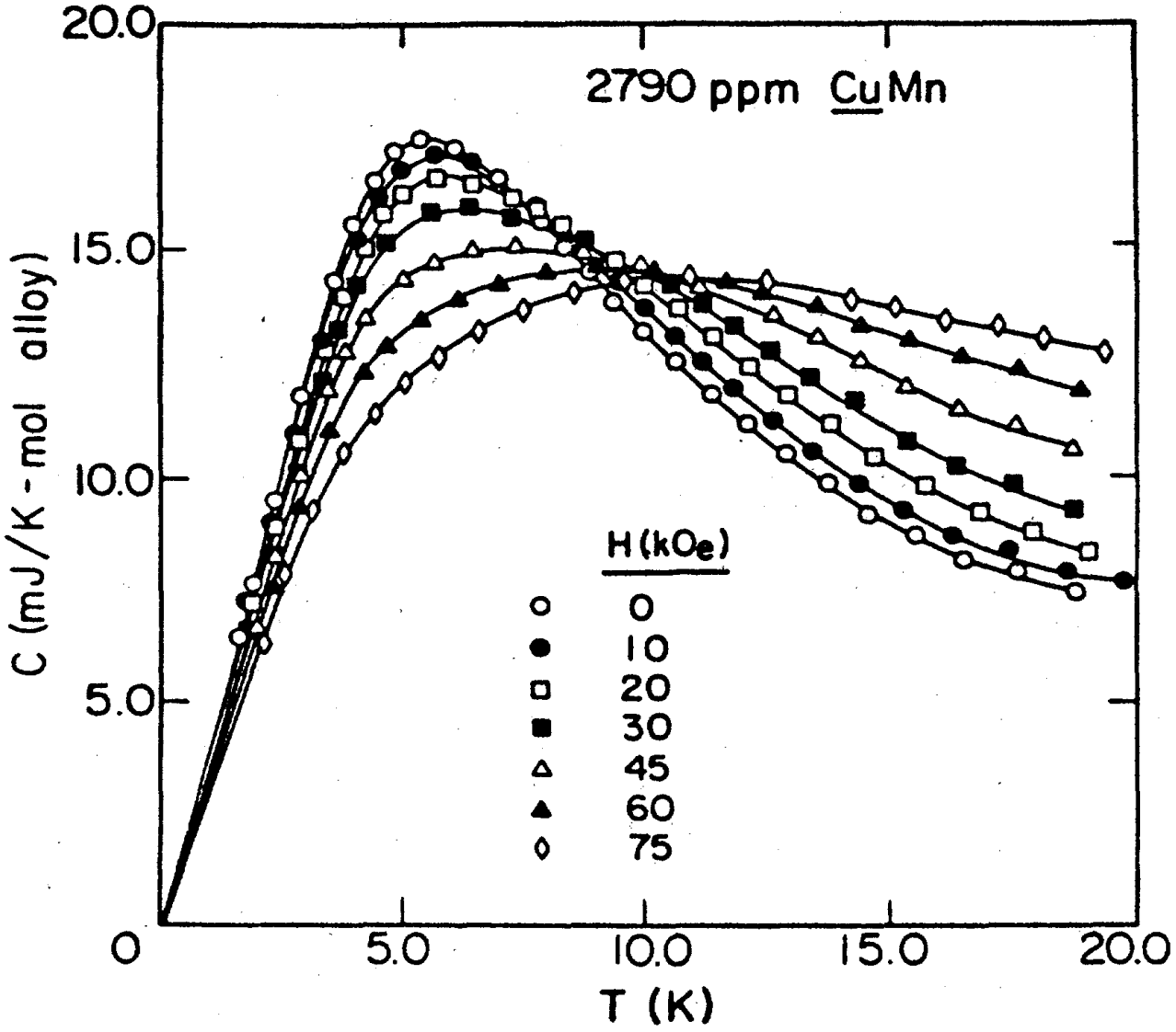
Transicio de fase i fenomens irreversibles



Comparacio amb un ferromagnet (Ising 2D)



Que fa el calor específic?

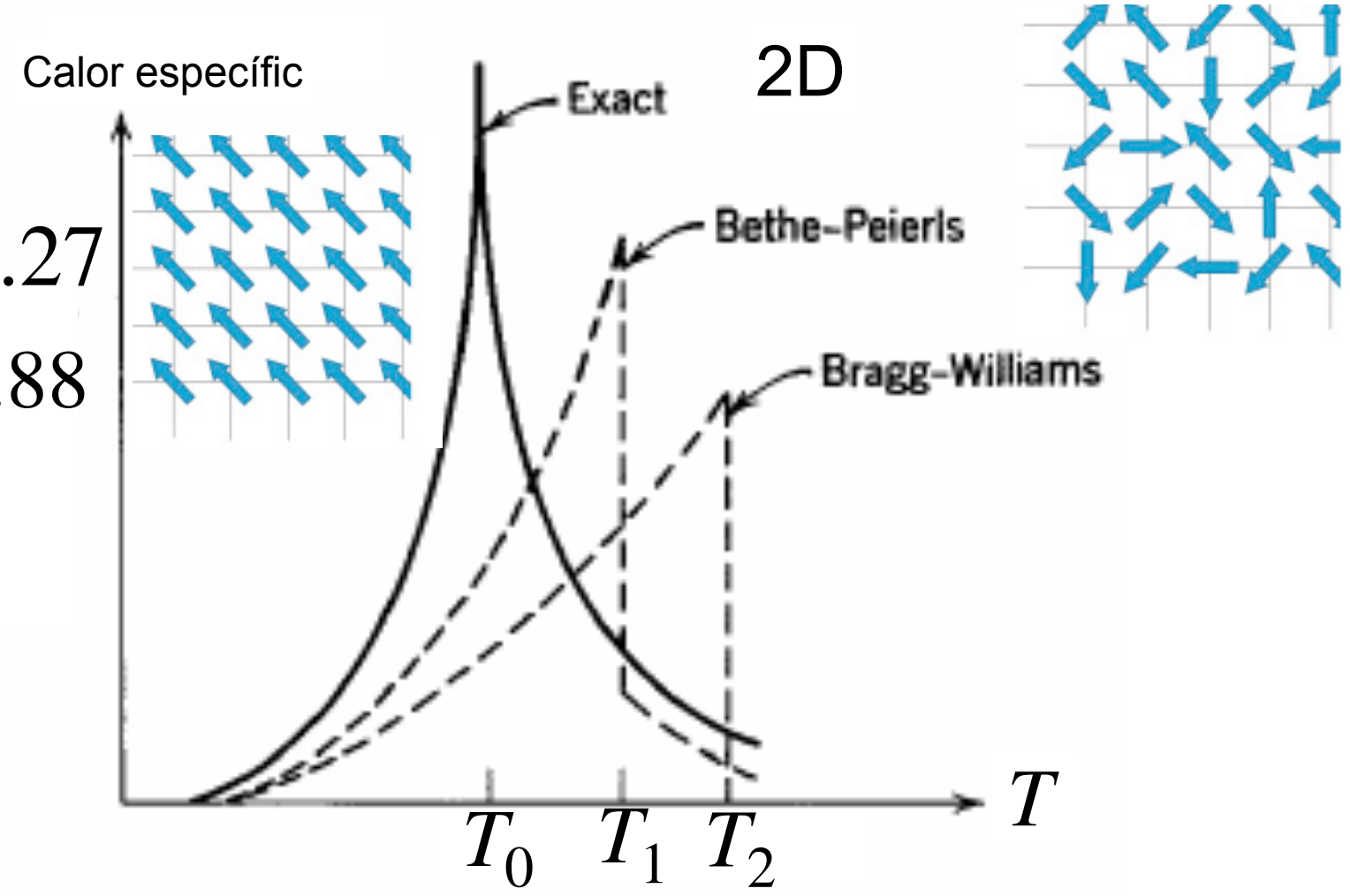


Comparació amb Ising

$T_0 = 2.27$

$T_1 = 2.88$

$T_2 = 4$



La primera teoria de vidre despi (1975)

Sam Edwards and Phil Anderson (Premi Nobel de Física, 1977)

$$E(\{s\}) = -\sum_{(i,j)} J_{ij} s_i s_j$$

J's aleatoris i distribuïts d'acord a una Gaussiana: $\overline{J_{ij}} = 0 \;\; ; \;\; \overline{J_{ij}^2} = J^2$

Física estadística del model

$$Z_J = \sum_{\{s\}} \exp\left(-\frac{E}{k_B T}\right) \;\; ; \;\; F_J = -k_B T \log Z_J$$

Qüestió

Com sumar sobre configuracions $\{s\}$ si les J's son aleatories?

Calculem $\overline{Z_J}$ o be $\overline{F_J}$?

$$\overline{F_J} = -k_B T \, \overline{\log Z_J}$$

Truc de la replica

$$\log x = \lim_{n \to 0} \frac{x^n - 1}{n}$$

$$\overline{Z_J^n} = \overline{Z_J Z_J \ldots Z_J}$$

Espai configuracional **replicat** n vegades: $\mathcal{S}_n = \{ s_i^{(1)} \cup s_i^{(2)} \cup \ldots s_i^{(n)} \}$

Parametre d'ordre de repliques

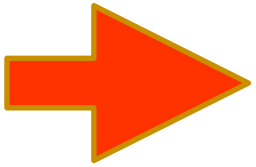
En el model de Ising el parametre d'ordre es la magnetizacio, $m = \langle s \rangle$

Per un vidre d'espí el parametre d'ordre és una matriu $n \times n$:

$$Q_{ab} = \langle s_a s_b \rangle \; ; \; a, b = 1,..,n$$

Solució més simple o simetria de rèpliques, $Q_{ab} = q \;\; , \; \forall a, b$

En el model de Ising, $q = m^2$

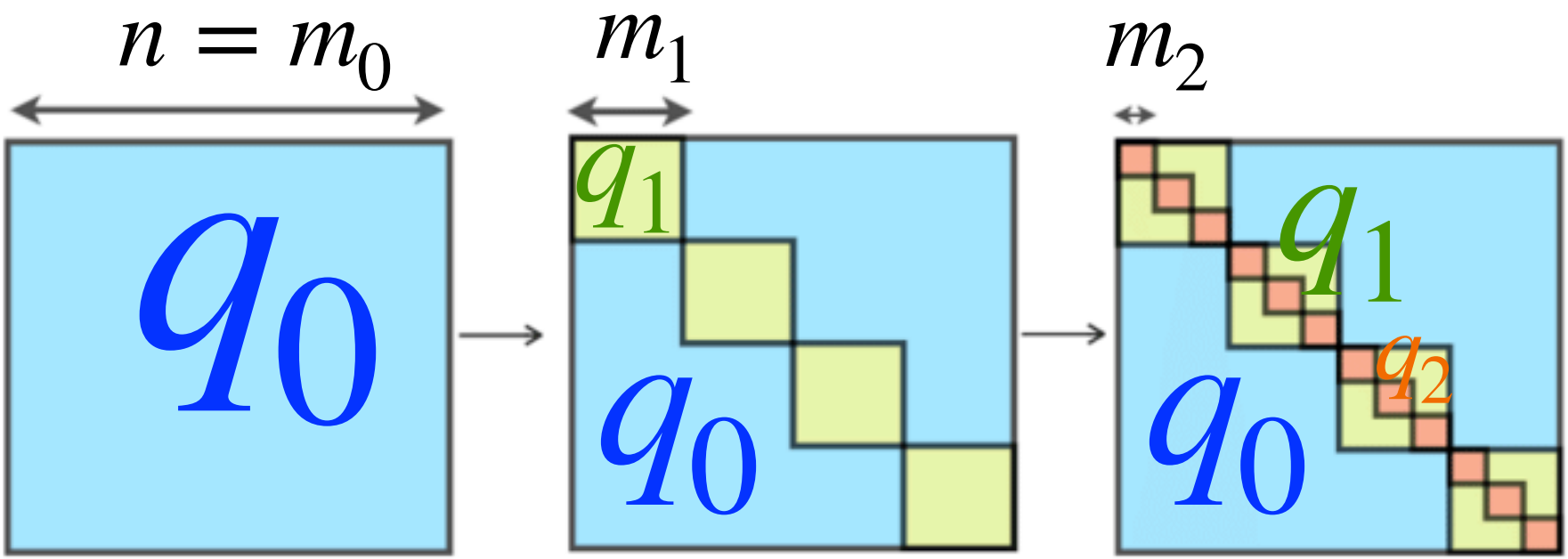


ENTROPIA NEGATIVA I TERMODINAMICAMENT INESTABLE

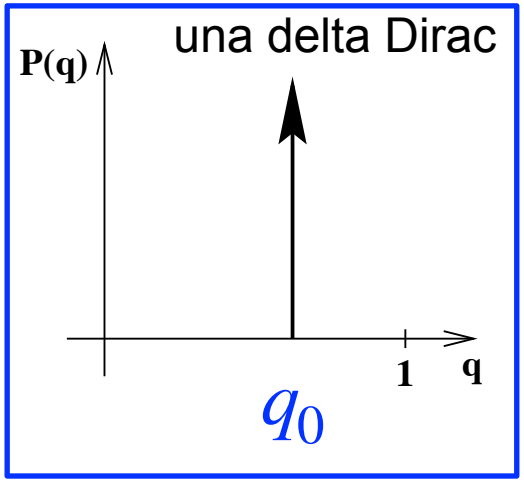
CAL TRENCAR LA SIMETRIA DE REPLIQUES

Q_{ab} ha de dependre de a i b

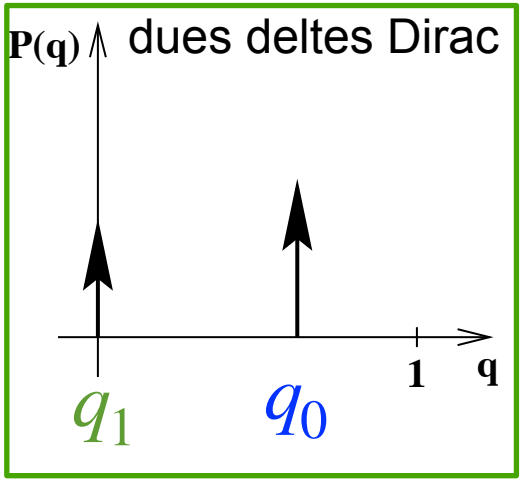
Trencament de simetria de repliques (RSB)



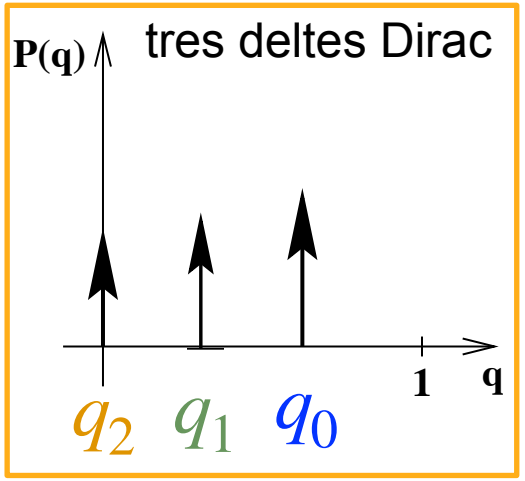
RS (replica simètric)



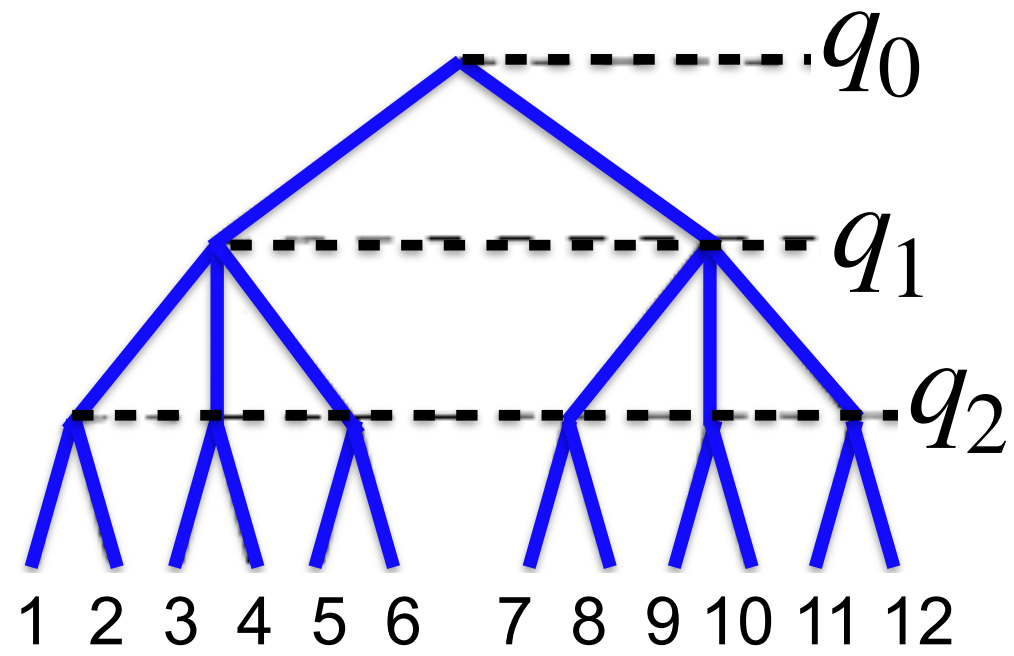
1-RSB

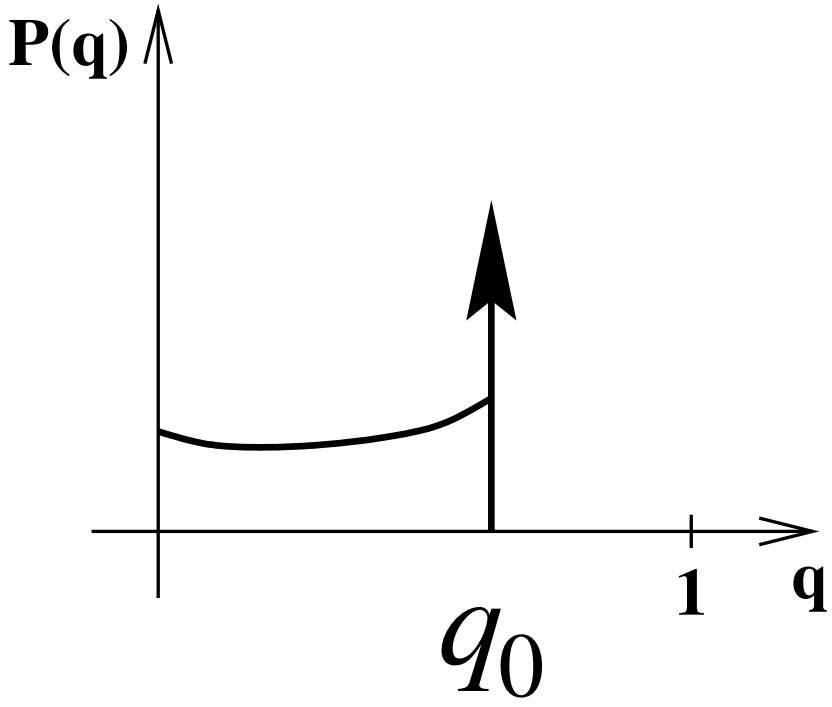


2-RSB



I aixi fins a l'infinit : $\infty - RSB$

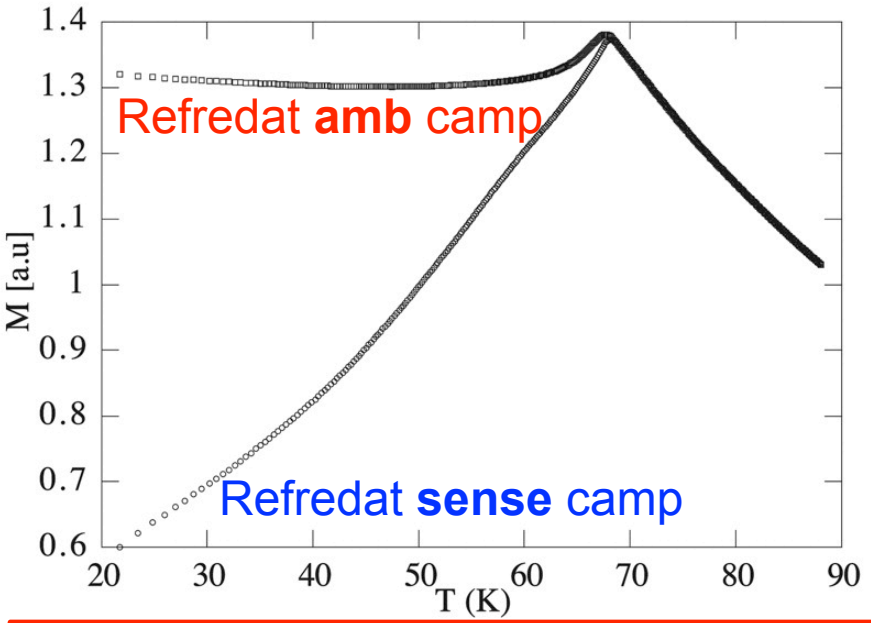


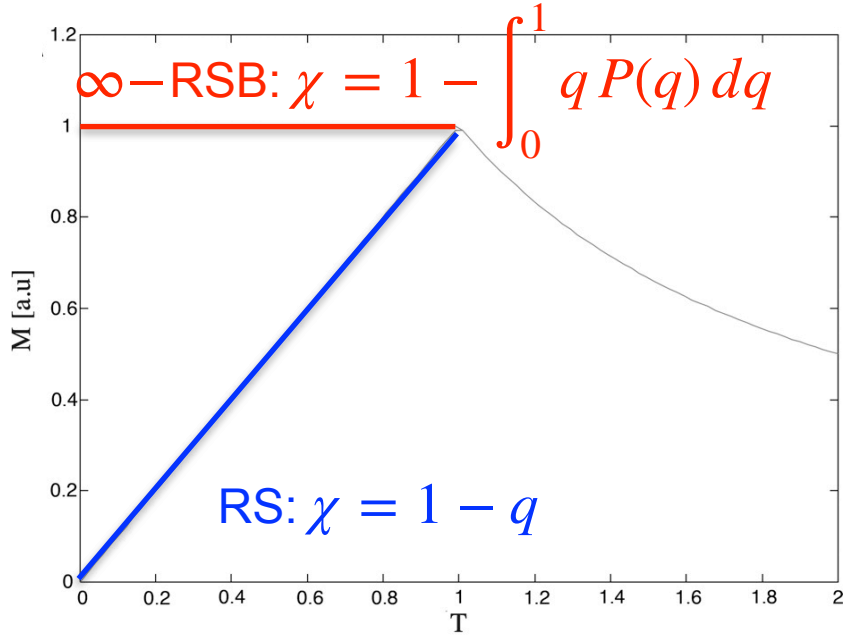


Susceptibilitat magnetica

$$\chi = 1 - \overline{q} = 1 - \int_0^1 q\, P(q)\, dq$$

Experiment i Teoria





INAUGURAL ARTICLE

Spin glasses and fragile glasses: Statics, dynamics, and complexity

PNAS May 23, 2006 103 (21) 7948-7955; https://doi.org/10.1073/pnas.0601120103

PNAS Proceedings of the National Academy of Sciences of the United States of America

Contributed by Giorgio Parisi, February 9, 2006

In this paper I will briefly review some theoretical results that have been obtained in recent years for spin glasses and fragile glasses. I will concentrate my attention on the predictions coming from the so called *broken replica symmetry* approach and on their experimental verifications. I will also mention the relevance or these results for other fields, and in general for *complex systems*.

Spin glasses: Experimental facts, theoretical concepts, and open questions

Review Modern Physics (1986)
176 pàgines, 1200 referències, 5800 cites

K. Binder

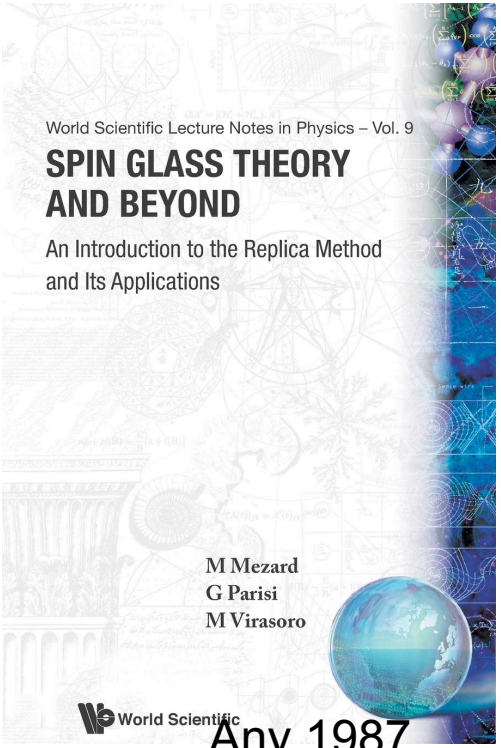
*Institut für Physik, Universität Mainz, D-6500 Mainz, West Germany**
and Institut für Festkörperforschung, Kernforschungsanlage Jülich, D-5170 Jülich, Postfach 1913, West Germany

A. P. Young

*Department of Physics, University of California, Santa Cruz, California 95064**
and Department of Mathematics, Imperial College of Science and Technology, London SX7 2BZ, England

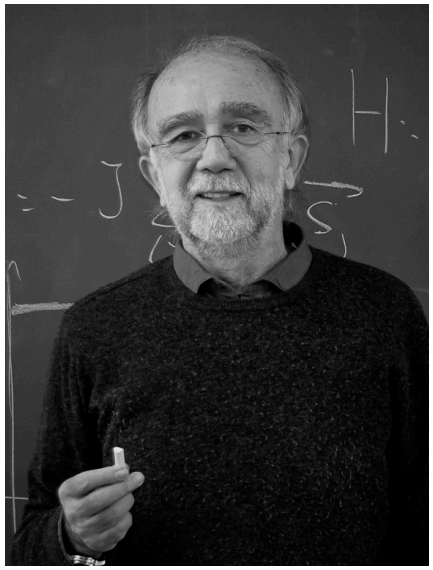
80's: dels vidres d'espí a les xarxes neuronals, la optimització combinatòria, als medis granulars, etc..

Marc Mezard, Giorgio Parisi, Miguel Virasoro



Any 1987

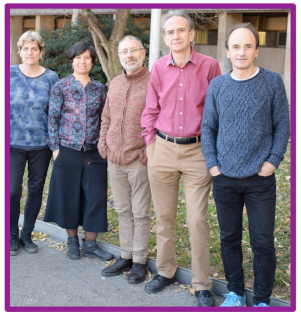
Als anys 80 hi havia el grup de magnetisme del Dr. Tejada (Batlle, Labarta, Martínez, Obradors,..)



Javier Tejada

PHYSICAL REVIEW B VOLUME 44, NUMBER 14 1 OCTOBER 1991-II

Correlated spin glass generated by structural disorder in the amorphous $Dy_6Fe_{74}B_{20}$ alloy



J. Tejada
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B. Martinez
Instituto de Ciencia de Materiales de Barcelona—C.S.I.C., Martí i Franqués, s/n, 08028 Barcelona, Spain

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E. M. Chudnovsky
Physics Department, Lehman College, The City University of New York, Bedford Park Boulevard West, Bronx, New York 10468
(Received 23 May 1991)

PHYSICAL REVIEW B VOLUME 46, NUMBER 14 1 OCTOBER 1992-II

Magnetic study of spin freezing in the spin glass $BaCo_6Ti_6O_{19}$: Static and dynamic analysis

A. Labarta and X. Batlle
Departament de Física Fonamental, Universitat de Barcelona, Avenida Diagonal 647, 08028 Barcelona, Spain

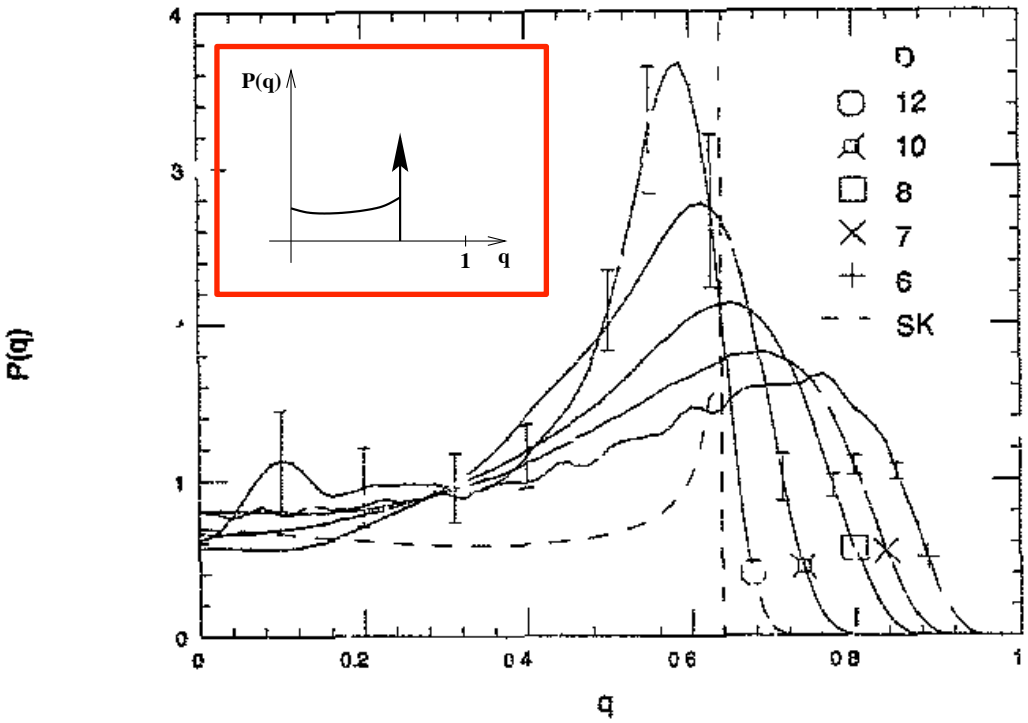
B. Martínez and X. Obradors
Institut de Ciència de Materials de Barcelona, C.S.I.C., Campus Universitat Autónoma de Barcelona, 08193 Bellaterra, Spain

Felix, necessito un teòric pels experiments que fem en vidres d'espí. El meu col.laborador a Roma, Dino Fiorani, coneix un tal Parisi que és molt bo.....

Al juny 1989 vaig a Roma, una aventura, sense casa ni res…m'hi vaig estar 1 mes in després desde 1990 a 1994 (5 anys) compartint despatx amb Parisi a Tor Vergata

Els dos primers articles amb el Giorgio

G. Parisi, F. Ritort and M. Rubi, JPA **24** (1991) 5307



Numerical results on a hypercubic spin-glass model

1991: PhD with G. Parisi and M. Rubí
1992-1994: Posdoc with G. Parisi

$$G_{(ab)(ab)} = P_1 = 1-\beta^2(1-p_1^2)/(ab)\in k \ ,$$
$$G_{(ab)(ab)} = P_0 = 1-\beta^2(1-p_0^2)/a\in k_1 b\in k_2 \ ,$$
$$G_{(ab)(ac)} = Q_0 = \beta^2(p_0^2-p_1)/a\in k_1 b,c\in k_2 \ ,$$
$$G_{(ab)(ac)} = Q_1 = \beta^2(p_1^2-p_1)/a,b,c\in k \ ,$$
$$G_{(ab)(ac)} = Q_2 = \beta^2(p_0^2-p_0)/a\in k_1 b\in k_2 c\in k_3 \ ,$$
$$G_{(ab)(ac)} = Q_3 = \beta^2(p_0 p_1-p_0)/a,b\in k_1 c\in k_2 \ ,$$
$$G_{(ab)(cd)} = R_0 = \beta^2(p_1^2-r_0)/a,b,c,d\in k \ ,$$
$$G_{(ab)(cd)} = R_1 = \beta^2(p_0 p_1-r_1)/a,b,c\in k_1 d\in k_2 \ ,$$
$$\text{or } a\in k_1 b,c,d\in k_2$$
$$G_{(ab)(cd)} = R_2 = \beta^2(p_1^2-r_2)/a,b,\in k_1 c,d\in k_2 \ ,$$
$$G_{(ab)(cd)} = R_3 = \beta^2(p_0^2-r_2)/a,c\in k_1 b,d\in k_2 \ ,$$
$$G_{(ab)(cd)} = R_4 = \beta^2(p_0 p_1-r_3)/a,b\in k_1 c\in k_2 d\in k_3 \ ,$$
$$\text{or } a\in k_1 b\in k_2 c,d\in k_3$$
$$G_{(ab)(cd)} = R_5 = \beta^2(p_0^2-r_3)/a\in k_1 b,c\in k_2 d\in k_3 \ ,$$
$$G_{(ab)(cd)} = R_6 = \beta^2(p_0^2-r_4)/a\in k_1 b\in k_2 c\in k_3 d\in k_4 \ .$$

R. Brunetti, G. Parisi, F. Ritort, PRB **46**(1992) 5339

Asymmetric Little spin-glass model

RSB en dimensio finita

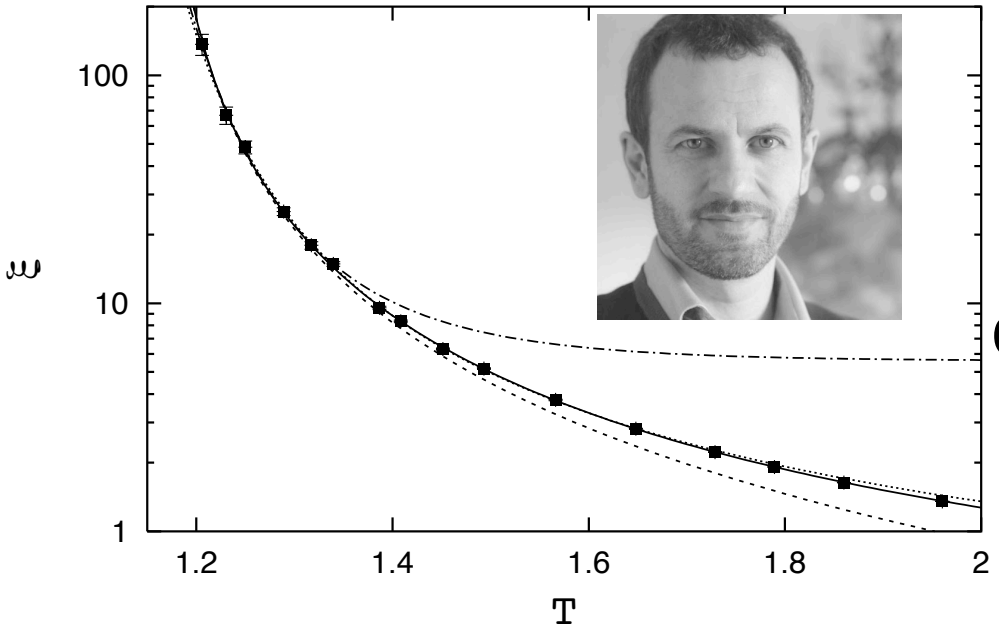
PHYSICAL REVIEW LETTERS

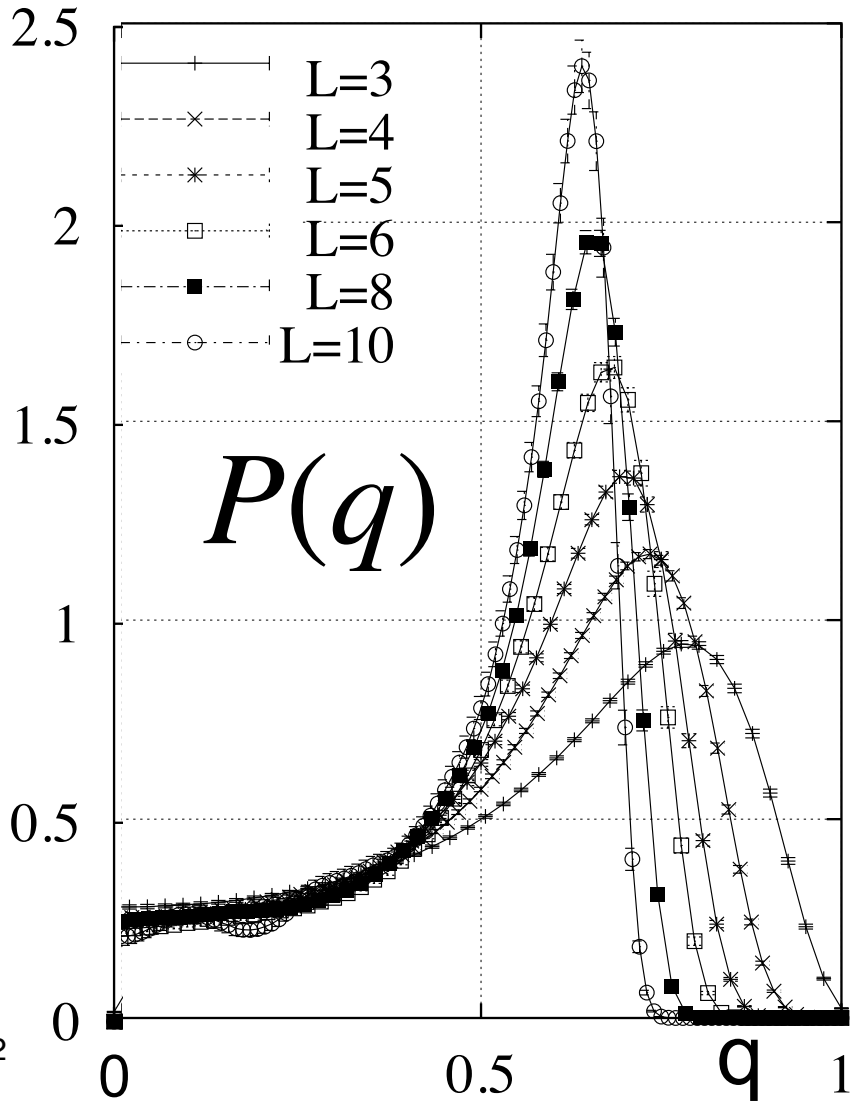
Universal Finite-Size Scaling Functions in the 3D Ising Spin Glass

Matteo Palassini
Department of Physics, University of California, Santa Cruz, California 95064
and Scuola Normale Superiore and INFM, 56100 Pisa, Italy

Sergio Caracciolo
Scuola Normale Superiore and INFN, 56100 Pisa, Italy
(Received 10 February 1999)

Matteo Palassini (UBICS)

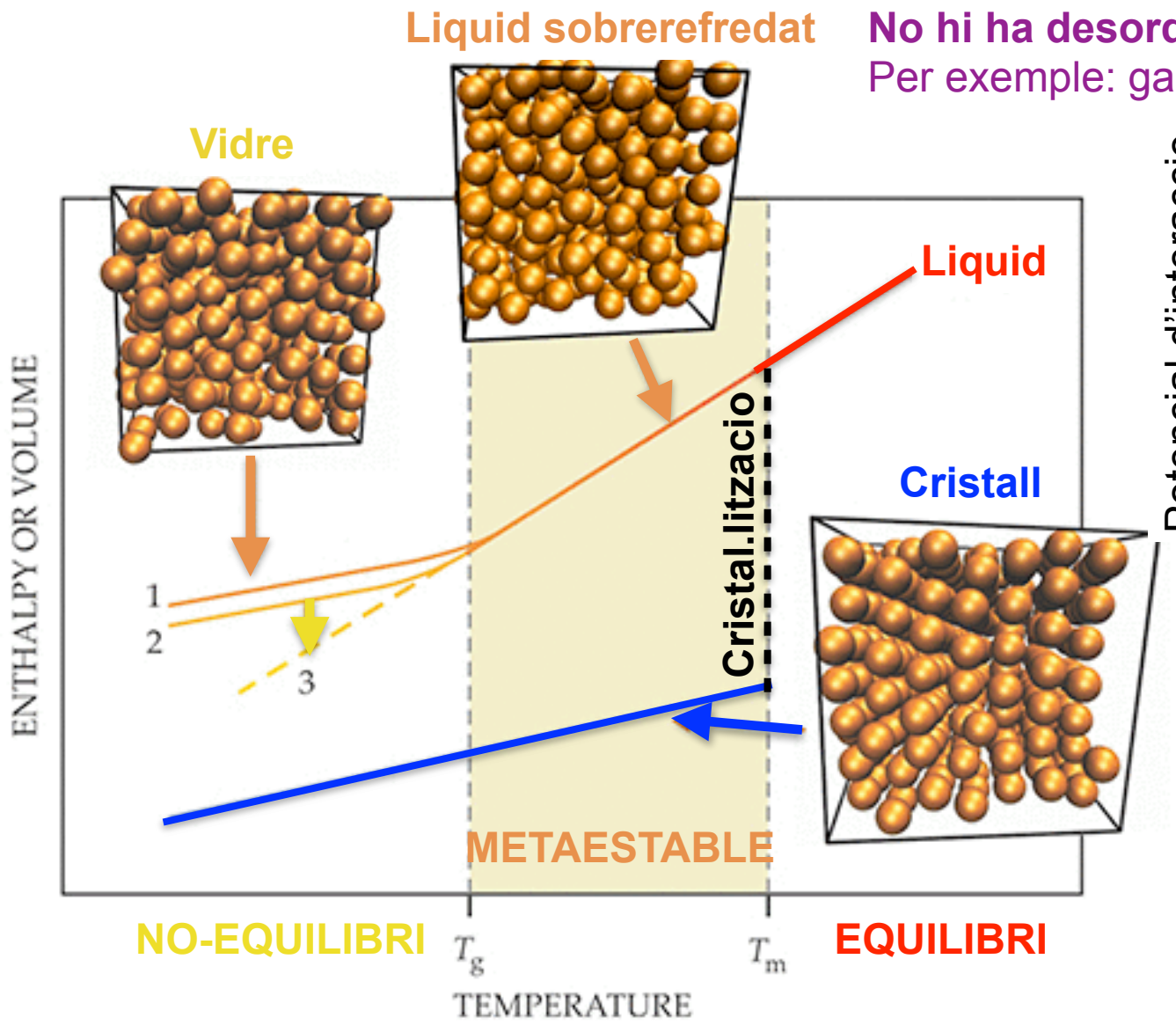




Longitut de correlació divergeix en D=3

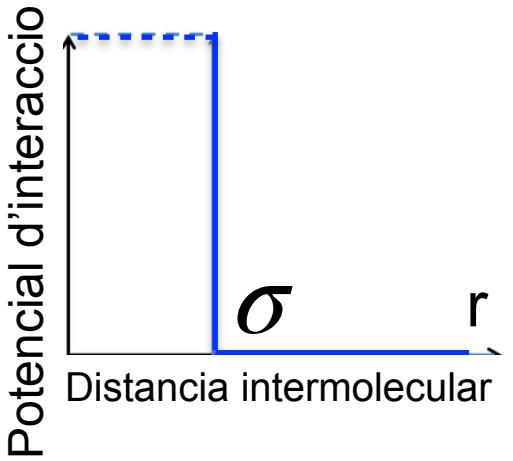
RSB en D=4

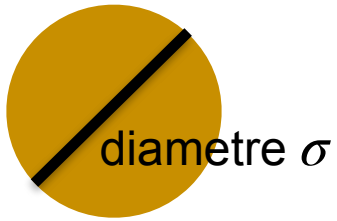
Dels vidres d'espí als vidres estructurals (90's)



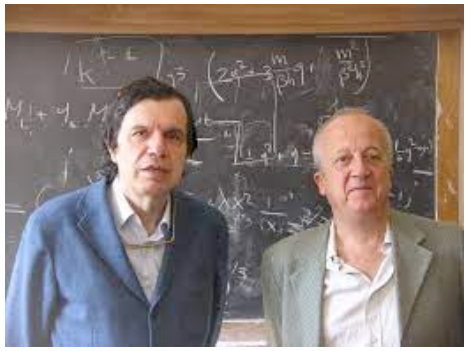
No hi ha desordre en les interaccions

Per exemple: gas d'esferes dures





ESFERA DURA



Giorgio Parisi Enzo Marinari

Replica field theory for deterministic models: I. Binary sequences with low autocorrelation J. Phys. A: Math. Gen. 27 (1994) 7615–7645.

Enzo Marinari†‡, Giorgio Parisi§ and Felix Ritort†§

† Dipartimento di Fisica and INFN, Università di Roma Tor Vergata, Viale della Ricerca Scientifica, 00133 Rome, Italy

‡ NPAC, Syracuse University, Syracuse, NY 13210, USA

§ Dipartimento di Fisica and INFN, Università di Roma La Sapienza, Piazzale Aldo Moro 2, 00187 Rome, Italy

$$s_i \rightarrow \hat{s}_p = \sum_i U_{pi} s_i$$ amb U_{pi} una rotació aleatoria

El model sense desordre (vidre estructural) es transforma en un vidre d'espí

VOLUME 74, NUMBER 6 PHYSICAL REVIEW LETTERS 6 FEBRUARY 1995

Matrix Models as Solvable Glass Models

L. F. Cugliandolo,* J. Kurchan,† and G. Parisi

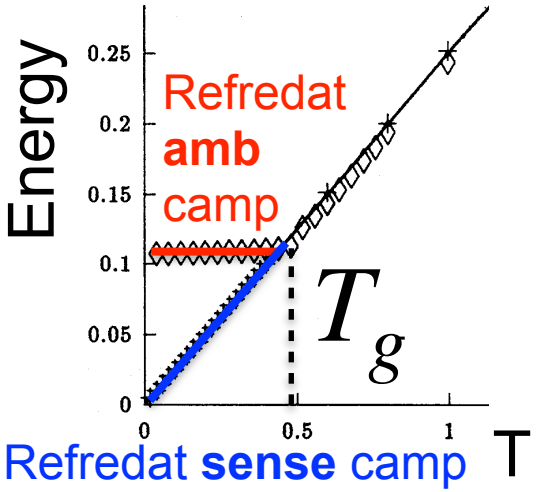
Dipartimento di Fisica, Università di Roma I, INFN-Sezione di Roma I, La Sapienza, Roma, Italy

F. Ritort

Dipartimento di Fisica, Università di Roma II, INFN-Sezione di Roma I, Tor Vergata, Roma, Italy

(Received 25 July 1994)

We present a family of solvable models of interacting particles in high dimensionalities without quenched disorder. We show that the models have a glassy regime with aging effects. The interaction is controlled by a parameter p. For $p = 2$ we obtain matrix models and for $p > 2$ "tensor" models. We concentrate on the cases $p = 2$ which we study analytically and numerically.



Refredat **sense** camp

PHYSICAL REVIEW LETTERS

Dynamic Scaling of Growing Interfaces

Mehran Kardar
Physics Department, Harvard University, Cambridge, Massachusetts 02138

Giorgio Parisi
Physics Department, University of Rome, I-00173 Rome, Italy

and

Yi-Cheng Zhang
Physics Department, Brookhaven National Laboratory, Upton, New York 11973

Equació KPZ (1986), 5900 cites

Tellus (1982) *34*, 10–16

Stochastic resonance in climatic change

By ROBERTO BENZI, *Istituto di Fisica dell'Atmosfera, C.N.R., Piazza Luigi Sturzo 31, 00144, Roma, Italy,*
GIORGIO PARISI, *I.N.F.N., Laboratori Nazionali di Frascati, Frascati, Roma, Italy,*
ALFONSO SUTERA, *The Center for the Environment and Man, Hartford, Connecticut 06120, U.S.A.*
and ANGELO VULPIANI, *Istituto di Fisica "G. Marconi", Università di Roma, Italy*

Ressonància estocàstica (1982), 1450 cites

PNAS

Interaction ruling animal collective behavior depends on topological rather than metric distance: Evidence from a field study

M. Ballerini*[†], N. Cabibbo[‡§], R. Candelier[‡¶], A. Cavagna*[‖]**, E. Cisbani[†], I. Giardina*[‖], V. Lecomte[†††‡‡], A. Orlandi*, G. Parisi*[‡§]**, A. Procaccini*[‡], and M. Viale[‡§§], and V. Zdravkovic*

*Centre for Statistical Mechanics and Complexity (SMC), Consiglio Nazionale delle Ricerche-Istituto Nazionale per la Fisica della Materia, [‡]Dipartimento di Fisica, and [§]Sezione Instituto Nazionale di Fisica Nucleare, Universita' di Roma "La Sapienza," Piazzale Aldo Moro 2, 00185 Roma, Italy; [†]Istituto Superiore Sanita', viale Regina Elena 299, 00161 Roma, Italy; [‖]Istituto dei Sistemi Complessi (ISC), Consiglio Nazionale delle Ricerche, via dei Taurini 19, 00185 Roma, Italy; and [††]Laboratoire Matière et Systèmes Complexes, (Centre National de la Recherche Scientifique Unite Mixte de Recherche 7057), Universite Paris VII 10 rue Alice Domon et Léonie Duquet, 75205 Paris Cedex 13, France

Comportament col.lectiu animal (2008), 1800 cites

Fully Developed Turbulence and Intermittency.

U. FRISCH
CNRS, Observatoire de Nice - BP 139, 06003 *Nice Cedex, France*

Turbulència desenvolupada (1985), 1400 cites

PHYSICAL REVIEW LETTERS **127,** 038001 (2021)

Editors' Suggestion

Long-Range Anomalous Decay of the Correlation in Jammed Packings

Paolo Rissone[1,*] Eric I. Corwin[2,†] and Giorgio Parisi[3,4,5,‡]
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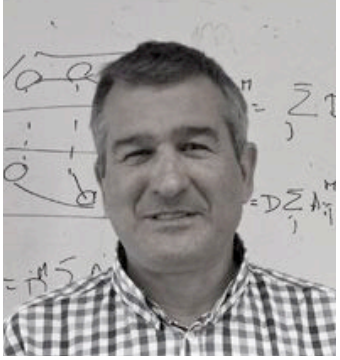
[4]*Istituto Nazionale di Fisica Nucleare, Sezione di Roma I, P.le A. Moro 5, 00185 Rome, Italy*
[5]*Institute of Nanotechnology (NANOTEC)-CNR, Rome unit, P.le A. Moro 5, 00185 Rome, Italy*

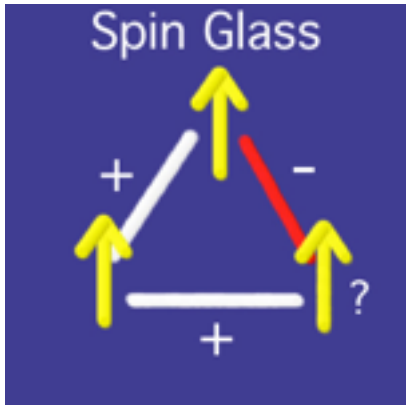
Paolo Rissone
Small Biosystems Lab

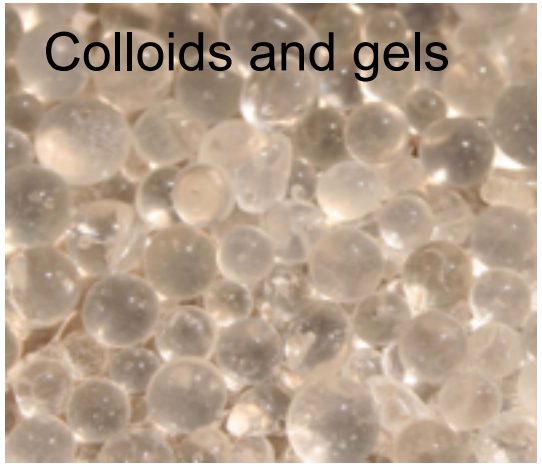


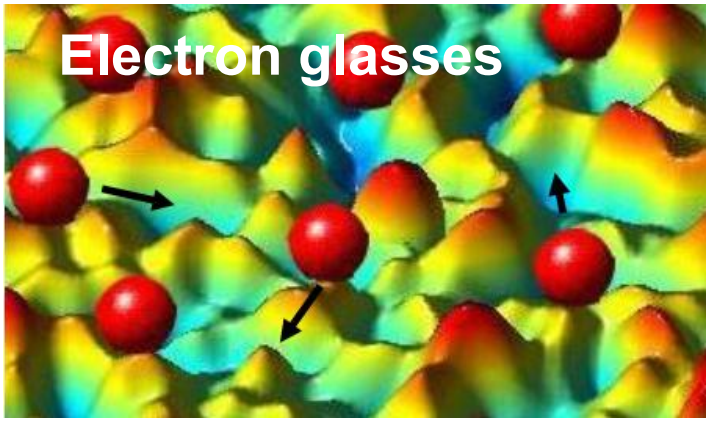
Master de Sistemes Complexos i Biofísica (UBICS)

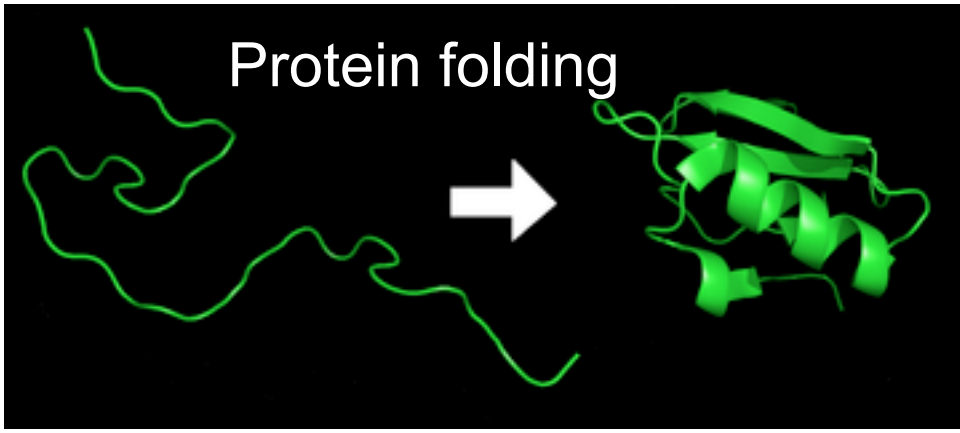
Albert Diaz-Guilera (UBICS)

Miquel Montero (UBICS)









La familia científica del Giorgio

Aniversari 70 anys (Setembre 2018)

Phil Anderson (Physics Nobel Prize 1977) ¨*La història del vidre d'espí pot ser el millor exemple que conec del dit que val la pena perseguir un misteri científic real fins als confins de la Terra, independentment de qualsevol importància pràctica o glamur intel·lectual.*"

Premis

Honors and awards [edit]

Giorgio Parisi is a foreign member of the French Academy of Sciences,[11] the American Philosophical Society,[12] and the United States National Academy of Sciences.[13]

- Feltrinelli Prize, 1986."Premi Antonio Feltrinelli". 15 May 2021.
- Boltzmann Medal, 1992.
- Dirac Medal of the ICTP, 1999.
- Enrico Fermi Prize, 2002.
- Dannie Heineman Prize for Mathematical Physics, 2005.
- Nonino Prize “An Italian Master of our Time”, 2005.
- Microsoft Award, 2007.
- Lagrange Prize, 2009.
- Max Planck Medal, 2011.
- Nature Awards for Mentoring in Science – Italy
- High Energy and Particle Physics Prize – EPS HEPP Prize, 2015.
- Lars Onsager Prize, 2016.
- Pomeranchuk Prize, 2018.
- Wolf Prize, 2021.
- Inserted in Clarivate Citation Laureates, 2021.
- Nobel Prize in Physics, 2021.