A statistical physics journey
(to the centre of LPTHE)

Leticia F. Cugliandolo

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leticia@lpthe.jussieu.fr

LPTHE, Paris, 2017

The group members

Volodya Dotsenko

@ LPTHE since ≈

1992

Marco Picco

1990

Leticia Cugliandolo

1997 (part-time)

2003 (full-time)

but also

Benoit Estienne

Benoit Douçot

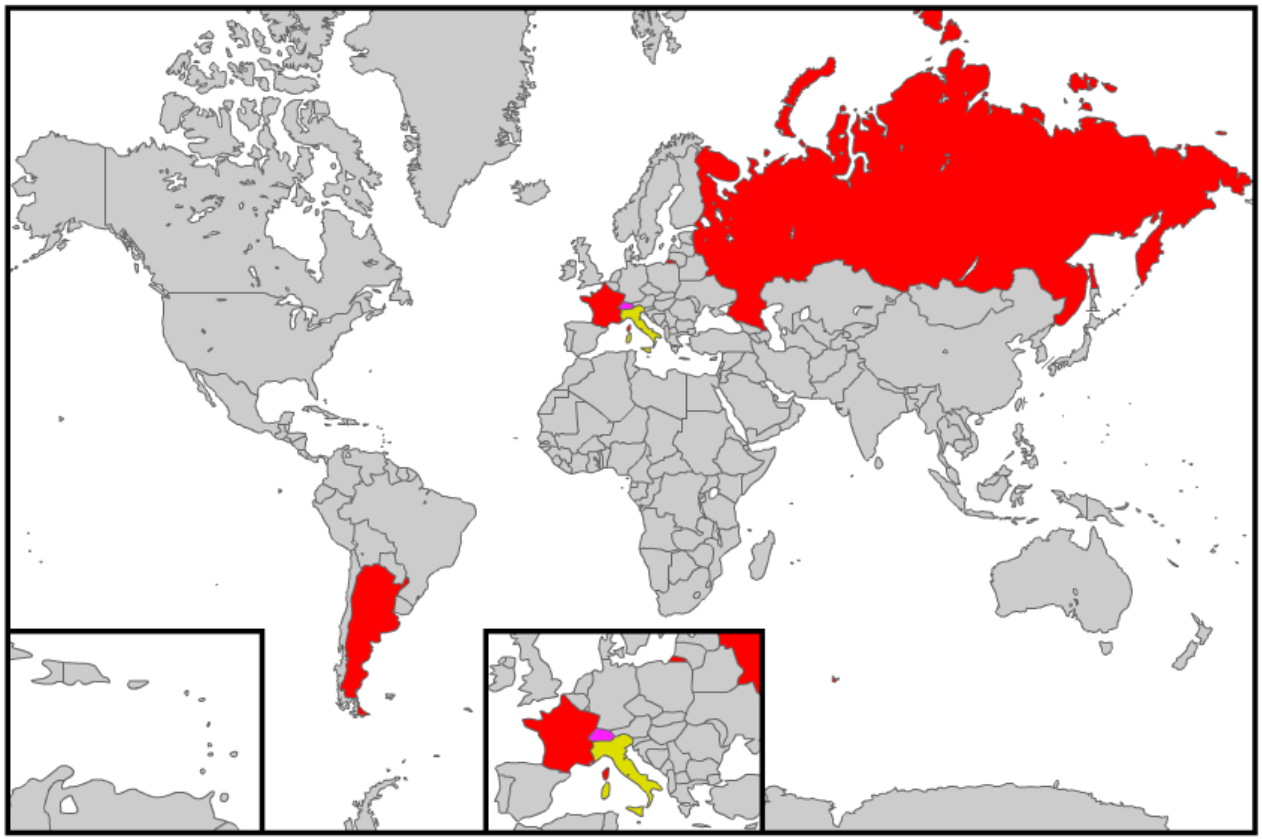
Lara Faoro

Lev Ioffe

Sofian Teber

Yacine Ikhlef

Origins



Quotes P-G de Gennes & J-P Sartre

La Plata, Argentina

Héctor de Vega

Fidel A. Schaposnik

La Plata, Argentina

Héctor de Vega

@ ENS 1974-76

@ Saclay 1977-79

@ LPTHE 1976 - 2015

Fidel A. Schaposnik

@ ENS 1974-76

@ Orsay 1977-78

@ LPTHE 1982, 85-86, 88, 1990

PhD group @ La Plata

Visits from LPTHE

Claude Viallet with Laura Schasponik Massolo @ F. A. Schaposnik's

Classical Topological Solutions

VOLUME 56, NUMBER 24 PHYSICAL REVIEW LETTERS 16 JUNE 1986

Electrically Charged Vortices in Non-Abelian Gauge Theories with Chern-Simons Term

H. J. de Vega and F. A. Schaposnik
Laboratoire de Physique Théorique et Hautes Energies,[a] *Paris, France*
(Received 28 March 1986)

It is shown that a non-Abelian gauge theory with Higgs fields and the addition of a Chern-Simons term in $2+1$ space-time dimensions exhibits finite-energy electrically charged vortex solutions. A novel feature of the vortices is that their electric charge Q is quantized in units of the fundamental charge e, $Q/e = n/2$ with n an integer, and their angular momentum is $J = Q/2e = n/4$.

Classical Topological Solutions

BOGOMOLNYI EQUATIONS FOR NON-ABELIAN CHERN-SIMONS-HIGGS THEORIES

By: CUGLIANDOLO, LF (CUGLIANDOLO, LF); LOZANO, G (LOZANO, G); MANIAS, MV (MANIAS, MV); SCHAPOSNIK, FA (SCHAPOSNIK, FA)
View ResearcherID and ORCID

MODERN PHYSICS LETTERS A
Volume: 6 **Issue:** 6 **Pages:** 479-486
DOI: 10.1142/S021773239100049X
Published: FEB 28 1991
View Journal Impact

Abstract

We study the non-abelian Chern-Simons theory with spontaneous symmetry breaking. We find Bogomol'nyi type or self-dual equations for a particular choice of the Higgs potential; the corresponding vortex solutions for G = SU(2) carry both quantized electric charge Q = -en/2 and angular momentum J = nm2/4 (e is the fundamental charge, n is an integer associated with the Chern-Simons coefficient, and m is another integer which labels the topological sector). We propose a straightforward generalization to the SU(N) case.

Classical Topological Solutions

e.g. Chern-Simons-Yang-Mills-Higgs model

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}D_\mu\phi D^\mu\phi + \frac{1}{4}D_\mu\psi D^\mu\psi - V(\phi,\psi)$$
$$+\frac{\mu}{4}\epsilon_{\mu\nu\alpha}[F^{\alpha\mu}A^\nu - \frac{2}{3}eA^\alpha(A^\mu \wedge A^\nu)] - V(\phi,\psi)$$

Field configurations with finite energy, not possible to smoothly transform them into the trivial vacuum, with a topological charge $Q \neq 0$.

Bogomol'nyi (@ LPTMS Orsay, quantum chaos) equations :

rewrite the action as $\mathcal{S} = Q + \int d^{d+1}x \ \sum_\mu (\mathrm{lhs}_\mu - \mathrm{rhs}_\mu)^2$

minimisation in each topological sector achieved by $(\mathrm{lhs}_\mu - \mathrm{rhs}_\mu)^2 = 0$

First order differential equations easier to solve than the second order Euler-Lagrange ones

Classical Topological Solutions

e.g. 2d XY model

$$H = -J \sum_{\langle ij \rangle} \vec{s}_i \cdot \vec{s}_j$$

Spin (angle) configurations that cannot be smoothly transformed into the trivial (uniform) ground state, with a topological charge $Q \neq 0$.

Kosterlitz-Thouless 1973

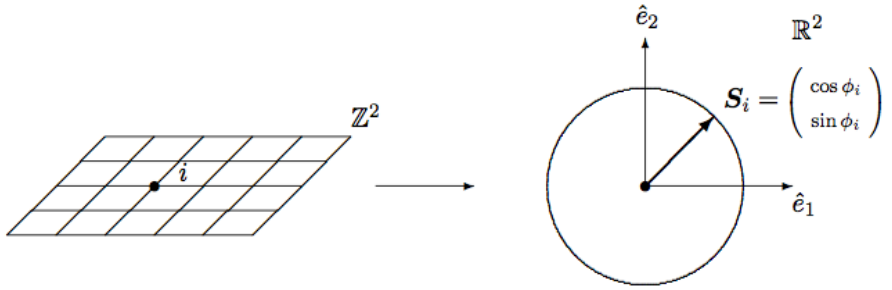
Topological phase transition

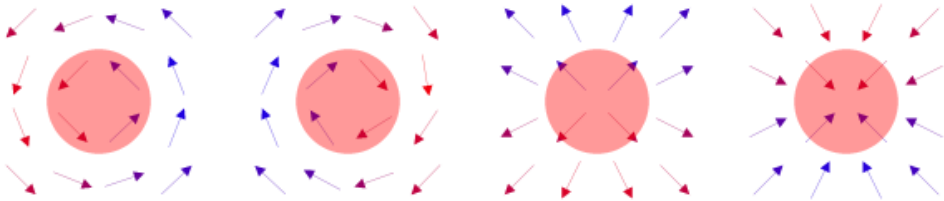
unbinding of vortex pairs

infinite order

$Q \propto$ number of spin turns

B. Douçot's talk





Classical Topological Solutions

e.g. 2d melting

$$H = \sum_i \frac{p_i}{2m} + \sum_{i \neq j} V(|\vec{r}_i - \vec{r}_j|)$$

Field configurations with finite energy, not possible to smoothly transform them into the trivial vacuum, with a topological charge $Q \neq 0$.

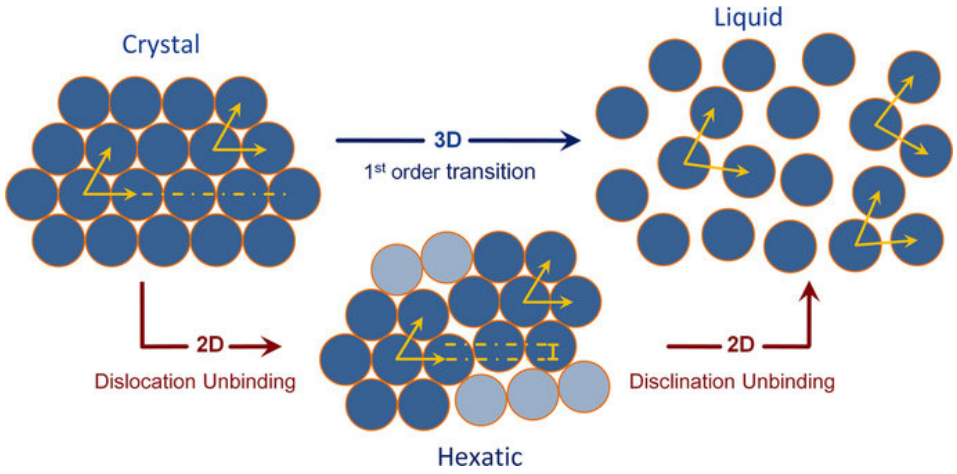
Kosterlitz-Thouless 1973

Topological phase transition

unbinding of dislocations

unbinding of disclinations

More later



Topological Quantum Field Th's

A quantum field theory which computes topological invariants (since it is not sensitive to changes in the shape of spacetime),

as expectation values of carefully chosen operators $\langle \hat{A} \rangle$

Donaldson, Jones, Witten $\approx$ 1988 & Kontsevich 

In condensed-matter physics, topological quantum field theories are the low-energy effective theories of topologically ordered states, such as fractional quantum Hall states, string-net condensed states, and other strongly correlated quantum liquid states.

B. Douçot's talk

Topological Quantum Field Th's

Topological Yang-mills Symmetry

L. Baulieu (Paris U., VI-VII) , I.M. Singer (Ecole Polytechnique & Ecole Normale Superieure)

Aug 12, 1988 - 17 pages

Nucl.Phys.Proc.Suppl. 5B (1988) 12-19

IN *ANNECY 1988, PROCEEDINGS, CONFORMAL FIELD THEORIES AND RELATED TOPICS* 12-19 AND PARIS XI UNIV. - LPTHE 88-18 (88,REC.JUL.) 17p

DOI: 10.1016/0920-5632(88)90366-0

Presented at Conference: C88-03-14.1 (Annecy Field Theory 1988:0012)

PAR-LPTHE-88/18, LPTENS-88/15

Volume 232, number 4 PHYSICS LETTERS B 14 December 1989

STOCHASTIC AND TOPOLOGICAL GAUGE THEORIES

Laurent BAULIEU [1]

CERN, CH-1211 Geneva 23, Switzerland

We show that the form of the Langevin equations for the stochastic quantization of a Yang–Mills theory in n-dimensional space is dictated by the geometrical structure. The arbitrary Lie algebra zero form, initially introduced by Zwanziger to induce a drift force along gauge orbits, is now defined as an additional gauge field component which permits stochastic time-dependent gauge transformations. The action of the functional integral representation of the Langevin equation is the same as that of an $(n+1)$-dimensional topological quantum field theory. Covariance between the stochastic time and the physical space directions is made possible. As an application, the action which generates Donaldson invariants in four-dimensional space is shown to be identical to the supersymmetric action describing the stochastic quantization of the three-dimensional Chern–Simons theory, which generates Jones invariants.

Topological Quantum Field Th's

Volume 224, number 4 PHYSICS LETTERS B 6 July 1989

TOPOLOGICAL FIELD THEORY AND TWO-DIMENSIONAL ABELIAN-HIGGS INSTANTONS

Fidel A. SCHAPOSNIK [1] and George THOMPSON

Laboratoire de Physique Théorique et Hautes Energies [2], Université Pierre et Marie Curie, Tour 16, 4, Place Jussieu, F-75252 Paris Cedex 05, France

Received 3 January 1989

We derive a topological field theory which describes the two-dimensional abelian-Higgs instanton (vortex) moduli space. In contrast to the three-dimensional monopole case here one explicitly breaks the gauge symmetry. Also a comparison is made with other supersymmetric models.

G. Thompson: at present, member of the High Energy Group and head of the Office of Associates & Federated Institutes at ICTP

Topological Quantum Field Th's

Volume 244, number 2 PHYSICS LETTERS B 19 July 1990

Path-integral measure for topological field theories

L.F. Cugliandolo, G. Lozano
Departamento de Fisica, Universidad Nacional de La Plata, CC 67, 1900 La Plata, Argentina and CONICET, Buenos Aires, Argentina

and

F.A. Schaposnik
LPTHE, Université Paris VI, Tour 16, 1er étage, 4, Place Jussieu, F-75252 Paris Cedex 05, France [1]
Departamento de Fisica, Universidad Nacional de La Plata, CC 67, 1900 La Plata, Argentina and Comisión de Investigaciones Científicas, Buenos Aires, Argentina

We discuss how the dependence of the path-integral measure on the metric affects the properties of topological quantum field theories. We show that the choice of an invariant measure (under general coordinate transformations) preserves the topological character of these theories. We also discuss how topological invariants should be computed within this approach.

Nuclear Physics B346 (1990) 507–526
North-Holland

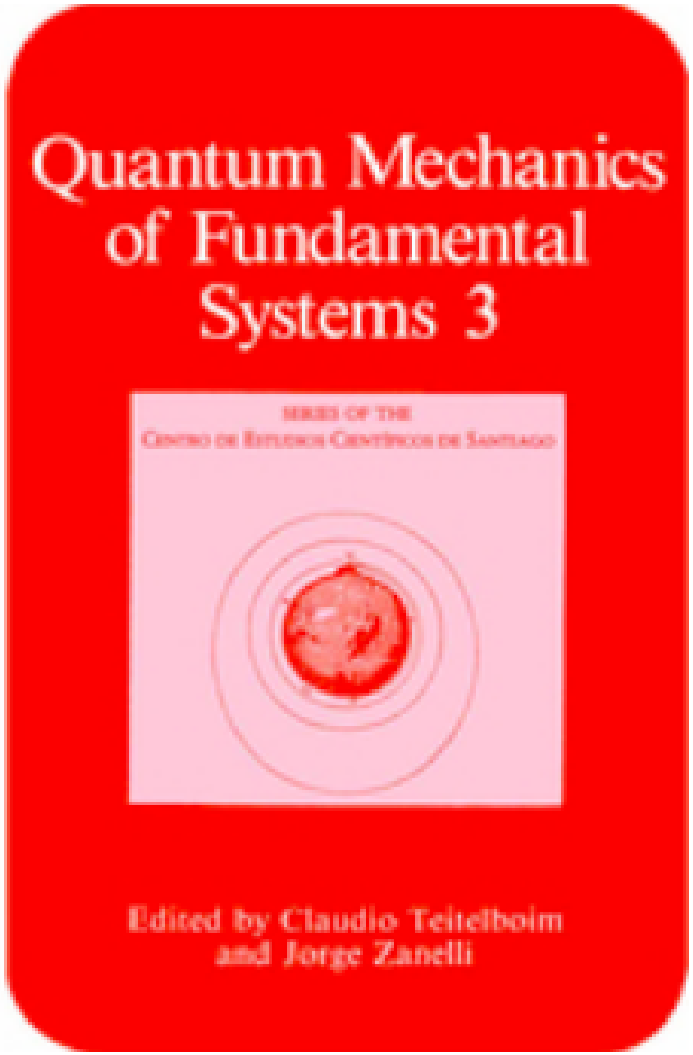
STOCHASTIC QUANTIZATION OF 2D GRAVITY AND ITS LINK WITH 3D GRAVITY AND TOPOLOGICAL 4D GRAVITY

Laurent BAULIEU[2], Adel BILAL[1] and Marco PICCO[2]
[1]*Theory Division, CERN, 1211 Geneva 23, Switzerland*
[2]*Laboratoire de Physique Théorique et Hautes Energies, Université Pierre et Marie Curie, 4, place Jussieu, 75252 Paris Cedex 05, France*

Marco Picco

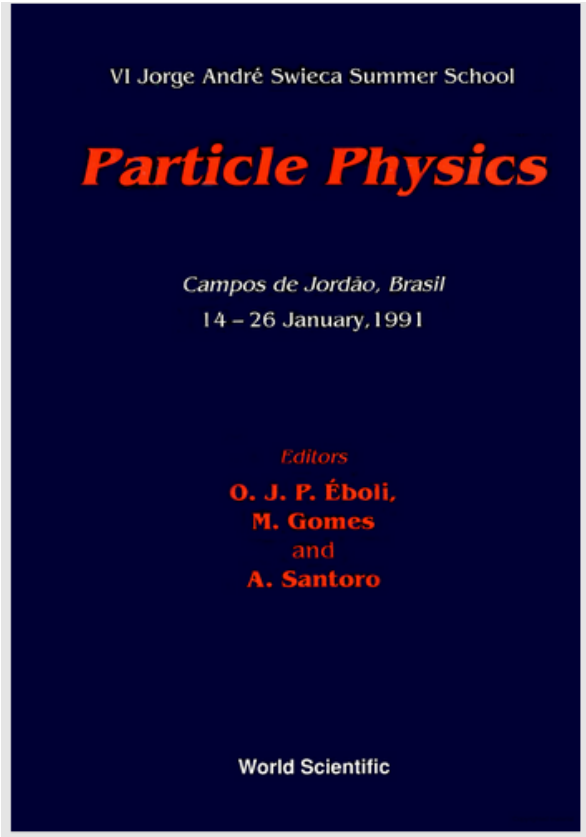
Parts of our "parallel" PhD theses, presented in 1991

CECS Santiago de Chile



Other participants: Daniel Cabra, Sergio Rica (Nice & Santiago), Max Bañados (Santiago)

Swieca Summer School



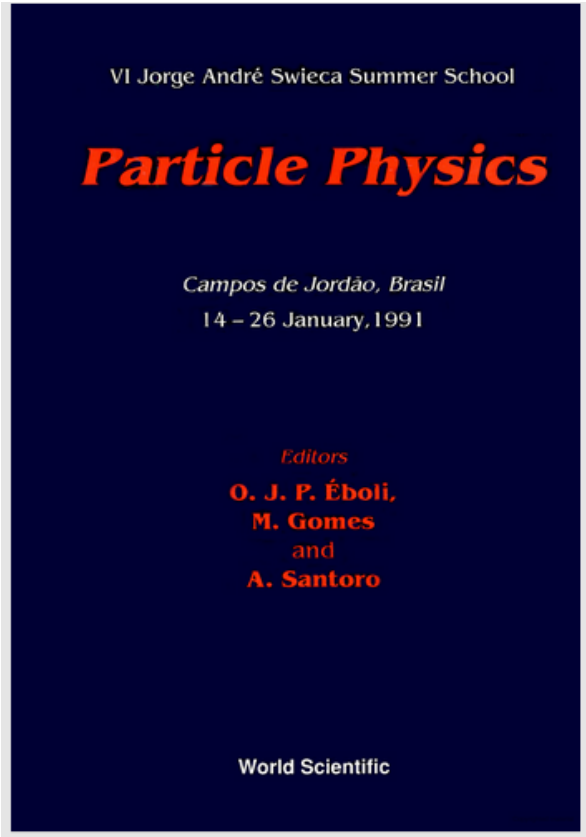
Campos do Jordão, State of São Paulo, Brazil

Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
23° 13°	19° 14°	18° 13°	14° 9°	16° 9°	16° 11°	17° 12°	17° 11°

Zuber J.-B., J. Swieca School `Particle Physics' pp. 522-559, Campos do Jordao, Brazil, Jan. 14-26, 1991 (eds.: Eboli O.J.P., Gomes M., Santoro A.), World Scientific, 1992, "KdV and W-flows", pdf file

Other participants: Clisthenis Constantinidis (Vitoria, @ LPTHE 01), Noureddine Mohammedi (Tours)

Swieca Summer School



Campos do Jordão, State of São Paulo, Brazil

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Zuber J.-B., J. Swieca School `Particle Physics' pp. 522-559, Campos do Jordao, Brazil, Jan. 14-26, 1991 (eds.: Eboli O.J.P., Gomes M., Santoro A.), World Scientific, 1992, "KdV and W-flows", pdf file

Other participants: Clisthenis Constantinidis (Vitoria, @ LPTHE 01), Noureddine Mohammedi (Tours)

Roma

LFC : post-doc @ Roma I “La Sapienza”

SAPIENZA
UNIVERSITÀ DI ROMA

1991-1994

Disordered systems

Attractor Neural Networks

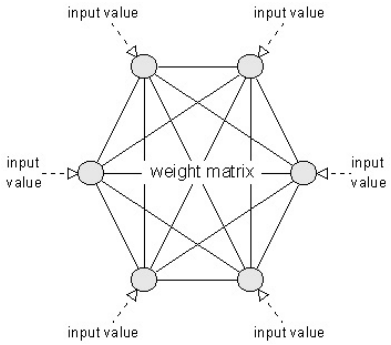
$H = \sum_{i \neq j} J_{ij} s_i s_j$ (Hopfield 1982) with $J_{ij} = \frac{1}{p} \sum_{\mu=1}^{p} \xi_i^{(\mu)} \xi_j^{(\mu)}$ (Hebb 1949)

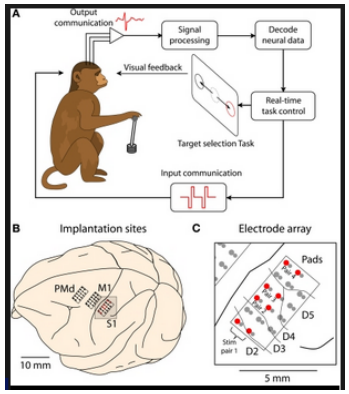
Neuron activity

$s_i = 1$ active $s_i = -1$ inactive

Symmetric couplings

Fully connected network





Senior professors: Daniel Amit & Miguel A. Virasoro (Roma I), Enzo Marinari & Giorgio Parisi (Roma II)

Other students & post-docs : Jorge Kurchan (LPS), Remi Monasson (LPT), Stefano Fusi (Columbia), Marc Potters (CFM), Felix Ritort (Barcelona), Misha Tsodyks (Weizmann), David Lancaster (UK)

Disordered systems

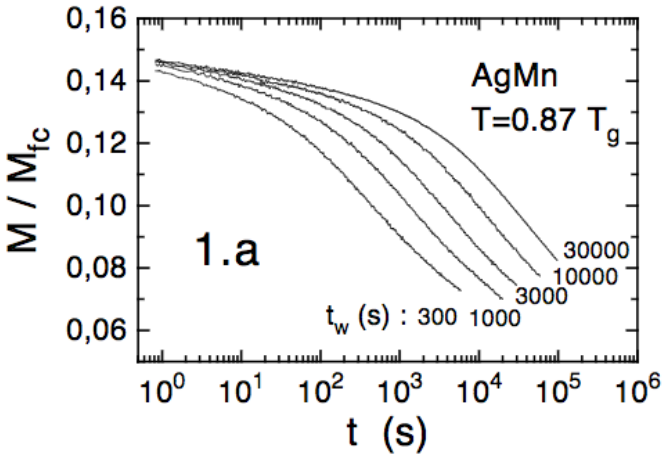
(Dynamics of) spin glasses

$$H = \sum_{i_1 \neq \cdots \neq i_p} J_{i_1 \ldots i_p} s_{i_1} \ldots s_{i_p}$$

p-psin disordered models

random coupling exchanges drawn from $P\left[J_{i_1 \ldots i_p}\right]$

Langevin dynamics (coupling to a bath) $\frac{ds_i}{dt} = -\frac{\delta H}{\delta s_i} + \xi_i$



Experiments @ Uppsala, Saclay, UCLA

out of equilibrium relaxation

Aging effects

Senior professors: Daniel Amit & Miguel A. Virasoro (Roma I), Enzo Marinari & Giorgio Parisi (Roma II)

Other students & post-docs : Jorge Kurchan (LPS), Remi Monasson (LPT), Stefano Fusi (Columbia), Marc Potters (CFM), Felix Ritort (Barcelona), Misha Tsodyks (Weizmann), David Lancaster (UK)

Disordered systems

In the 80s @

Russian Academy of Sciences
Landau Institute for Theoretical Physics

125. M.V. Feigelman, L.B. Ioffe, *The Statistical Properties of the Hopfield Model of Memory*, Europhys. Lett., 1 (4), 197-201 (1986).

126. M.V. Feigel'man, L.B. Ioffe, *Relaxation in spin-glasses far above the transition point*, J. Phys. France, 47 (3), 363-366 (1986).

127. L.B. Ioffe, M.V. Feigel'man, *Asimmetriya vzaimodeistvii i ierarkhiya obrazov v modelyakh assotsiativnoi pamyati*, Pis'ma v ZhETF, 44 (3), 148-150 (1986) [L.B. Ioffe, M.V. Feigel'man, *Interaction asymmetry and hierarchy of patterns in associative-memory models*, JETP Lett., 44 (3), 189-192 (1986)].

128. L.B. Ioffe, M.V. Feigel'man, *Spinovye stekla i modeli pamyati*, Uspekhi fiz. nauk, 150 (2), 323-325 (1986) [L.B. Ioffe, M.V. Feĭgel'man, *Spin glasses and models of memory*, Sov. Phys. Usp. 29(10), 986-988 (1986)].

Lev Ioffe

From 1983

Neural Network

Spin glasses

since 2012 @ LPTHE

Disordered systems

In the 80s @

Russian Academy of Sciences
Landau Institute for Theoretical Physics

60. Vik.S. Dotsenko, Vl.S. Dotsenko, *Critical behaviour of the phase transition in the 2D Ising Model with impurities*, Adv. Physics, 32 (2), 129-172 (1983), WoS: A1983RA61700001.

61. Vik.S. Dotsenko, Vl.S. Dotsenko, *Critical behaviour of the 2D Ising model with impurity bonds*, J. Phys. C 15 (3), 495-507 (1982).

62. Vik.S. Dotsenko, Vl.S. Dotsenko, *Two-point correlation function of the 2D Ising model with impurity lattice bonds*, J. Phys. C 15(17), L557-L563 (1982).

63. Vik.S. Dotsenko, Vl.S. Dotsenko, *Kriticheskoe povedenie korrelyatsionnoi funktsii modeli Izinga s primesnymi svyazyami*, ZhETF, 83 (2), 727-742 (1982) [Vik.S. Dotsenko, Vl.S. Dotsenko, *Critical behavior of the correlation function of the Ising model with impurity bonds*, Sov. Phys. JETP, 56(2), 406-414 (1982)].

64. Vik.C. Dotsenko, Vl.S. Dotsenko, *Fazovyi perekhod v 2D modeli Izinga s primesnymi svyazyami*, Pis'ma v ZhETF, 33 (1), 40-44 (1981) [Vik.S. Dotsenko, Vl.S. Dotsenko, *Phase transition in the 2D Ising model with impurity bonds*, JETP Lett., 33 (1), 37-40 (1981)].

Volodya Dotsenko

Effects of weak disorder on $2d$ critical phenomena &

the ordered phases

(e.g. $J_{ij} > 0$, no frustration)

Conformal Field Theory

Roma

Marco Picco : post-doc @ Roma II “Tor Vergata”

Castelli Romani

w/Felix Ritort & Elisabetta Pallante

Senior professors: Daniel Amit & Miguel A. Virasoro (Roma I), Enzo Marinari & Giorgio Parisi (Roma II)

Other students & post-docs : Jorge Kurchan (LPS), Remi Monasson (LPT), Stefano Fusi (Columbia), Marc Potters (CFM), Felix Ritort (Barcelona), Misha Tsodyks (Weizmann), David Lancaster (UK)

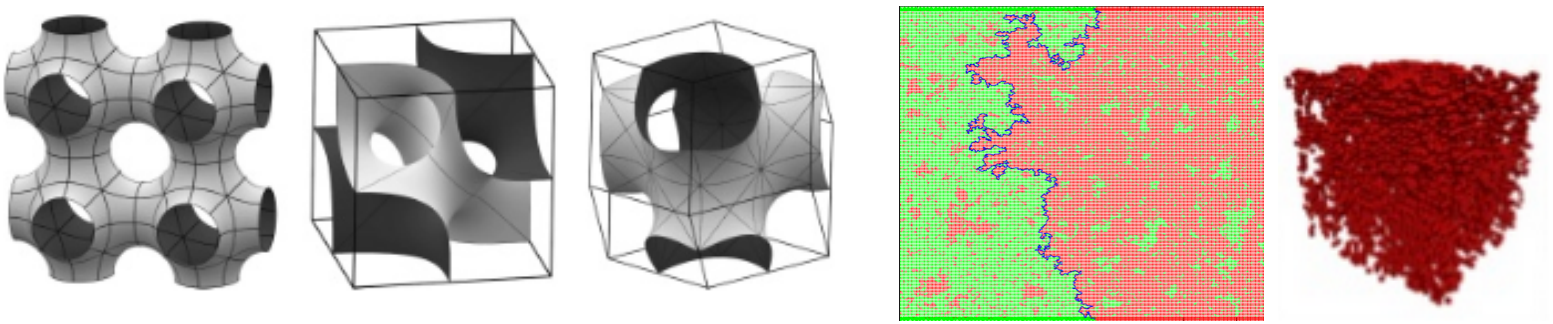
Critical models

Geometry & Disorder

In 1992 Dotsenko @ LPTHE, Picco @ Roma II

Geometry and statistics of the surfaces surrounding critical clusters at T_p and T_c in the $3d$ Ising model

Study of ensembles of self-avoiding random surfaces, motivated by string theory



Dotsenko, Harris, Marinari, Martinec, Picco & Windey 93-95

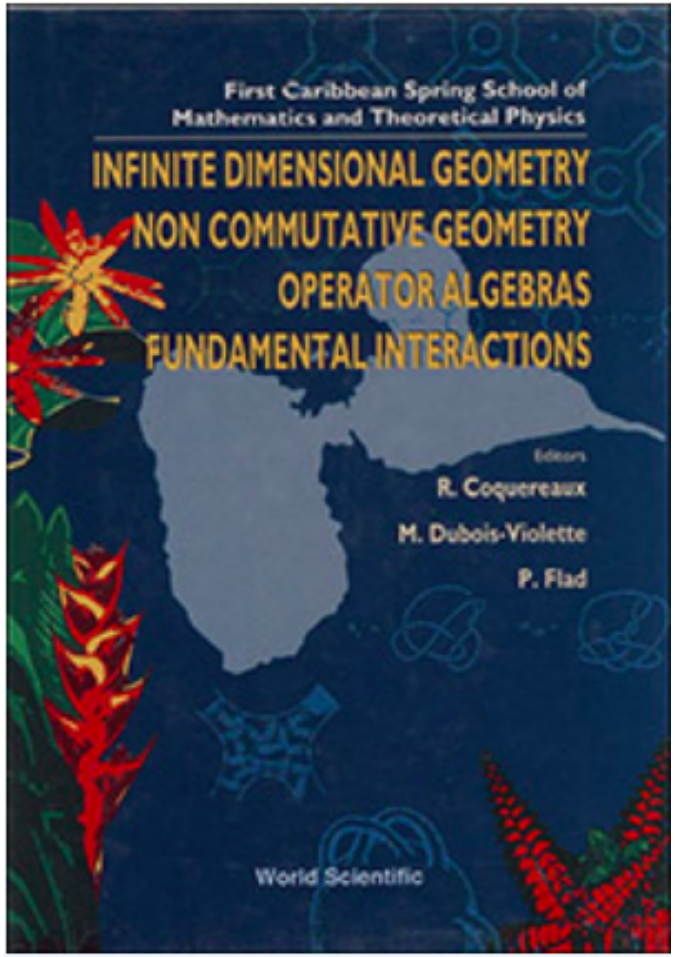
Guadeloupe

Infinite Dimensional Geometry, Noncommutative Geometry, Operator Algebras and Fundamental Interactions

Proceedings of the First Caribbean Spring School of Mathematics and Theoretical Physics

First Caribbean Spring School of Mathematics and Theoretical Physics
Saint-François-Guadeloupe, 30 May – 13 June 1993

Edited by: **R Coquereaux** (*CNRS, France & Centre de Physique Théorique, France*), **M Dubois-Violette** (*CNRS, France & University of Paris-Sud, France*), **P Flad** (*CNRS, France & University of Paris-Sud*)



Lectures by

Laurent Baulieu

Michel Talon

Paris

Marco

1993

Volodya

$\simeq$ 1991

Leticia

1994

1997

2003

Lev

1991

2012

Present

What do we do now ?

Field Theory and StatPhys

Equilibrium

Parafermionic Conformal Field Theories (q state Potts models)

Higher order correlation functions in Conformal Field Theories

V. Dotsenko, B. Estienne, M. Picco, R. Santachiara,

Conformal bootstrap approach to percolation & criticality

More on the structure of equilibrium clusters at criticality

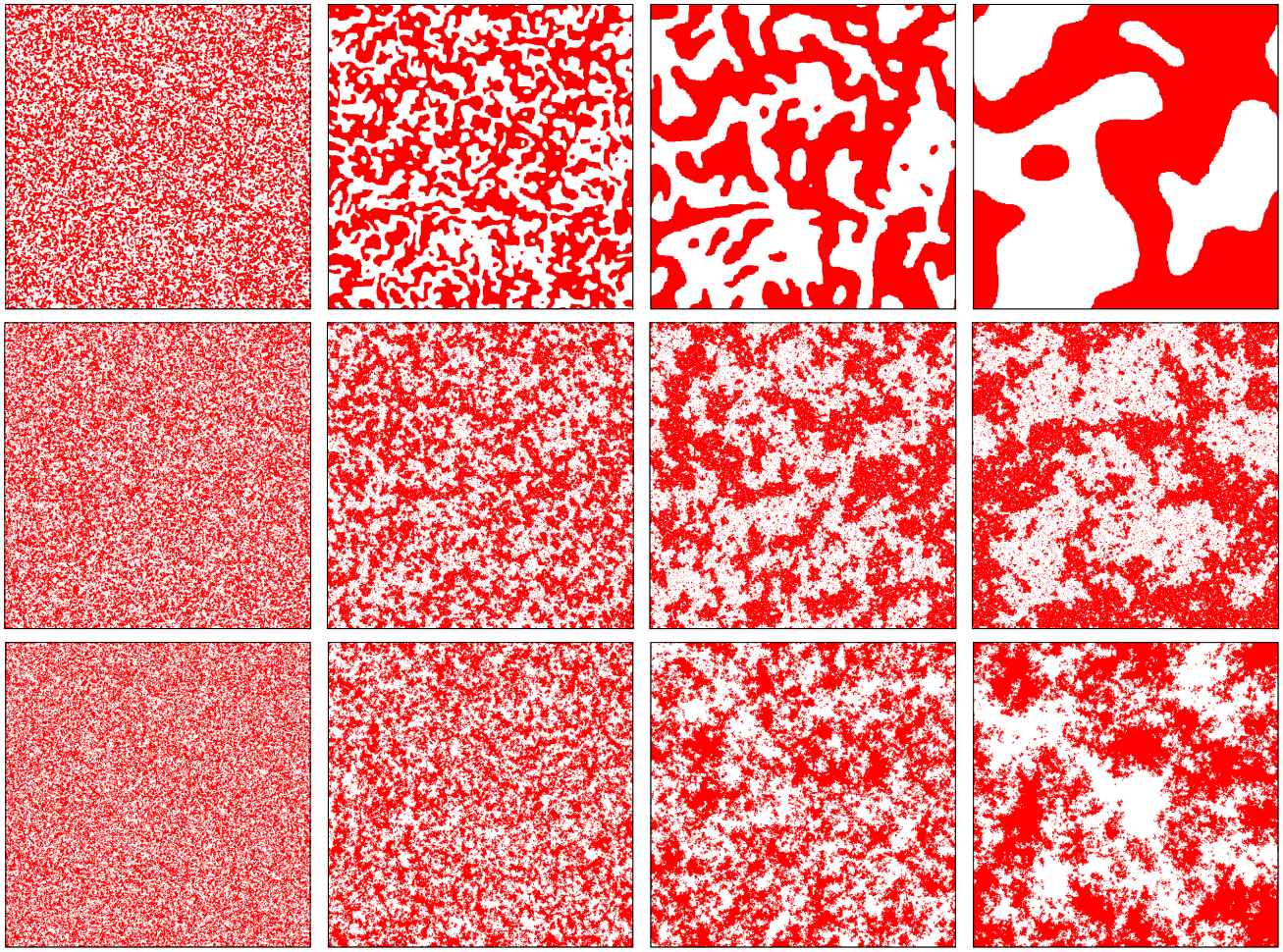
M. Picco & R. Santachiara

The random field Ising model (issues on dimensional reduction)

M. Picco & N. Sourlas

Coarsening in spin models

Geometry in real space : snapshots at $t = 4,\ 64,\ 512, 4096$ MCs



Ising

$T = 0$

T_c

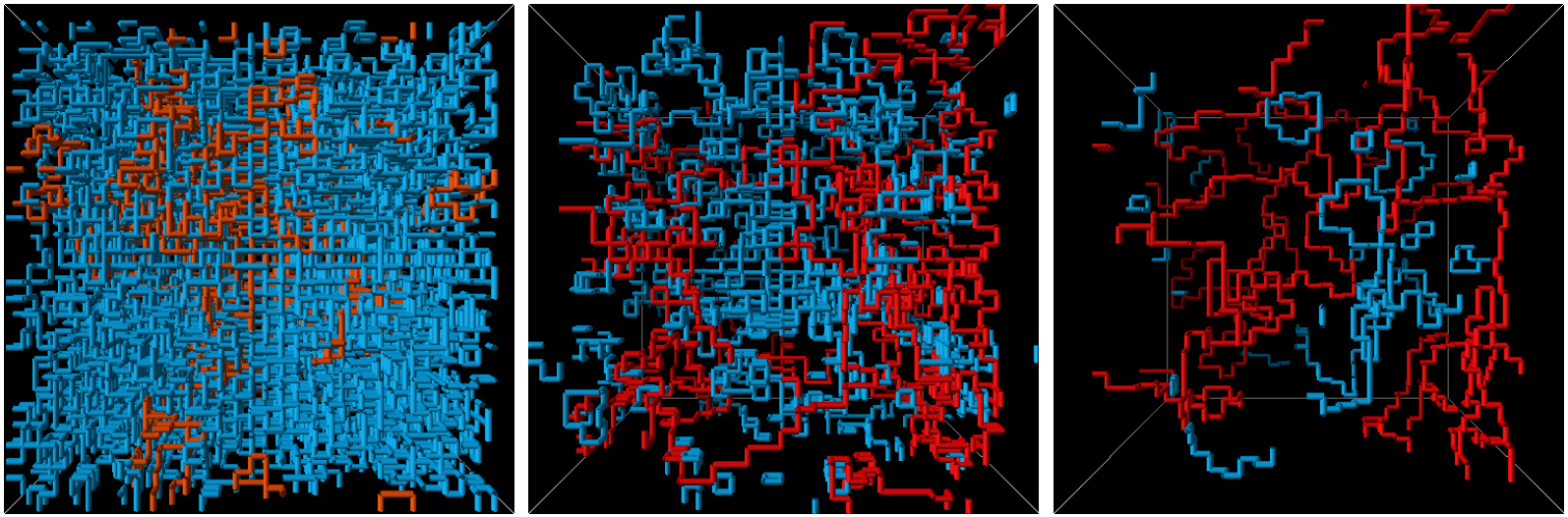
Voter

T. Blanchard, H. Ricateau, A. Sicilia & A. Tartaglia

Coarsening in Field Th's

Progressive elimination of vortex loops after a quench

$T \gg T_c$ $\qquad\qquad$ $T = 0$

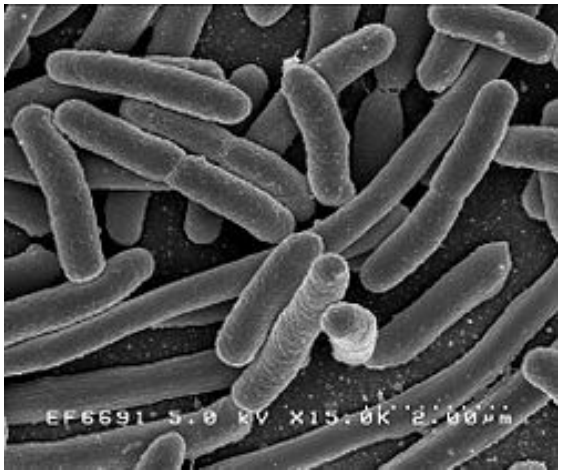


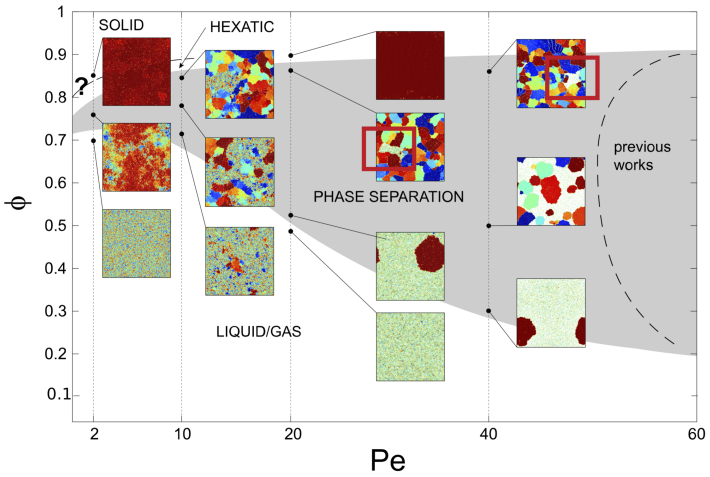
$t = 0$ $\qquad$ $t = 3$ $\qquad$ $t = 5$

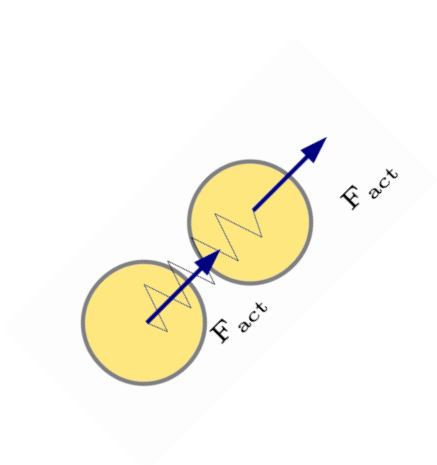
U(1) field theory in $3d$: Bose-Einstein condensates, Helium, etc.

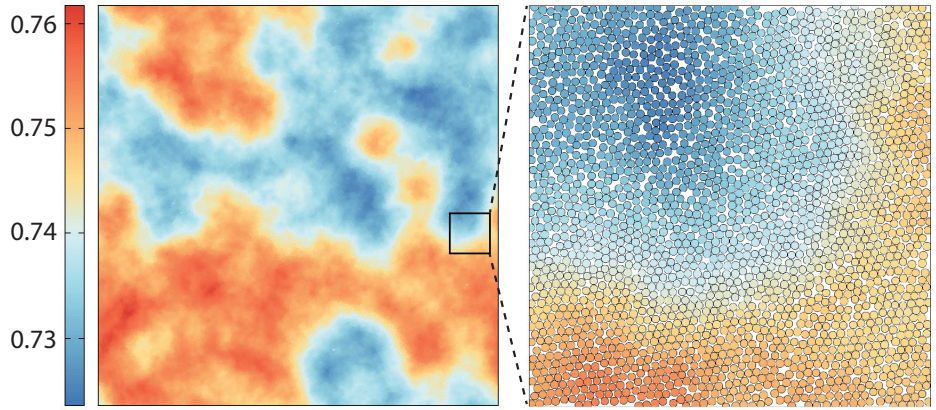
Active matter

Phase diagram & the classical melting problem in $2d$



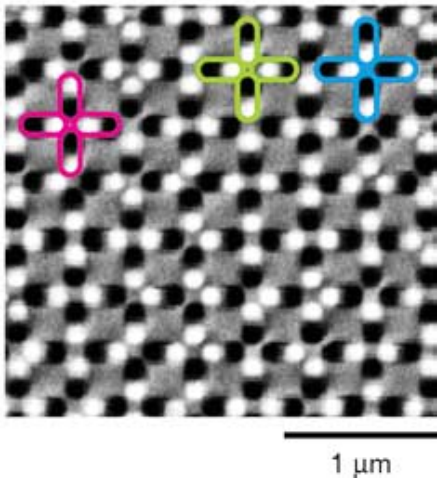


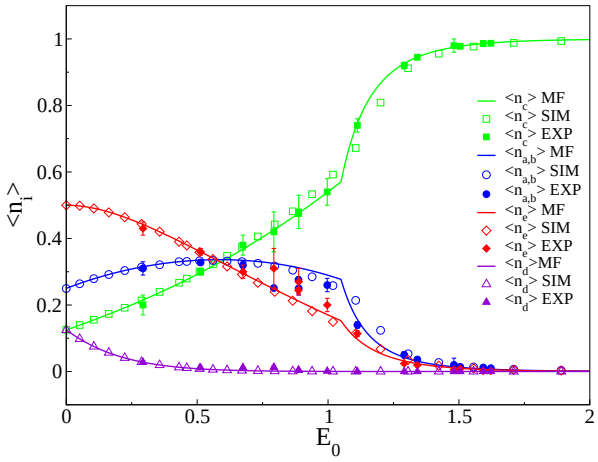


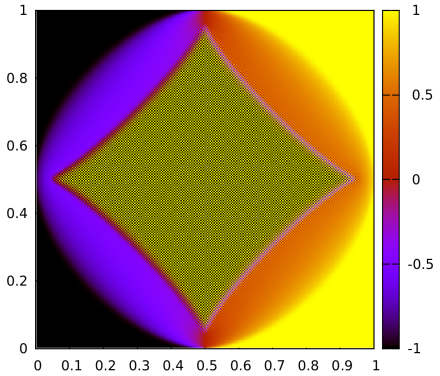


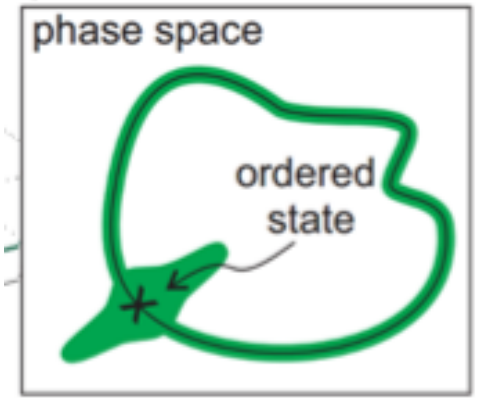
Frustrated magnetism

Artificial spin ice and vertex models





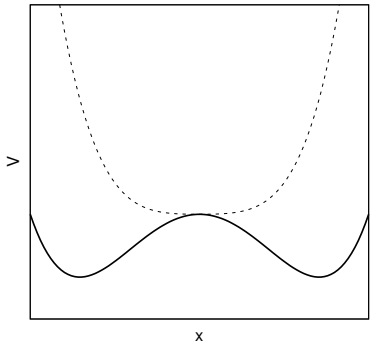


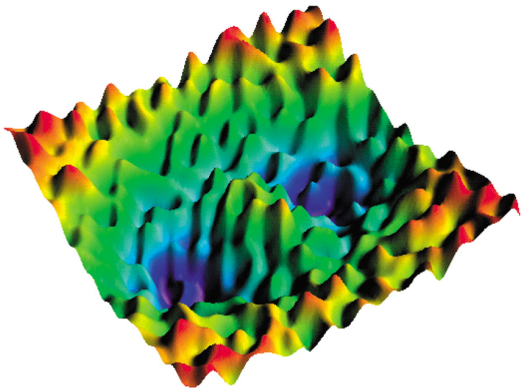


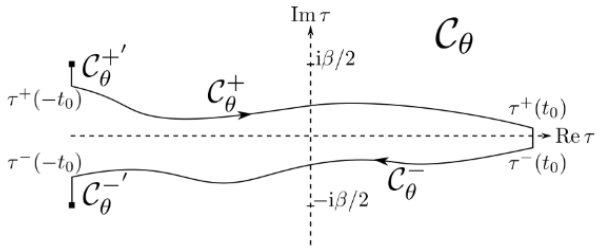
D. Levis, L. Foini & M. Tarzia (LPTMC)

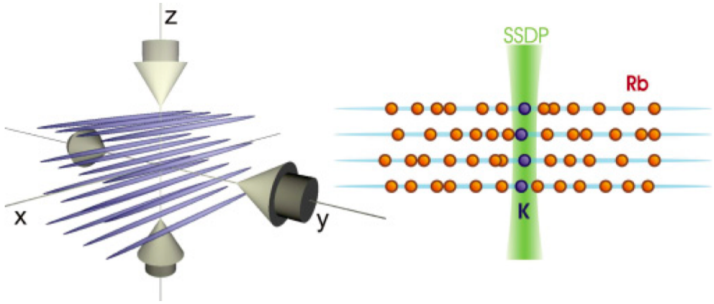
Quantum physics

Out of equilibrium









Dynamics after quenches in isolated systems

rôle of disorder

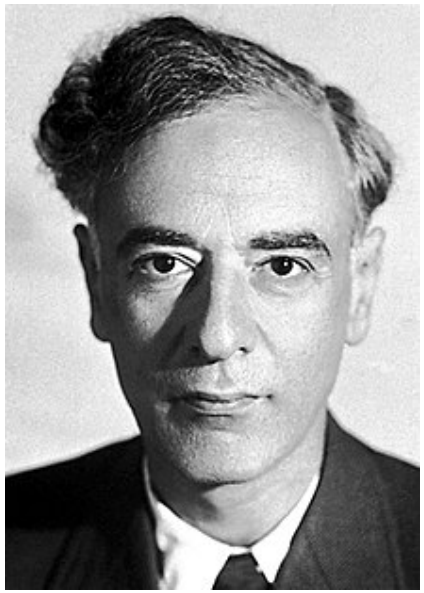
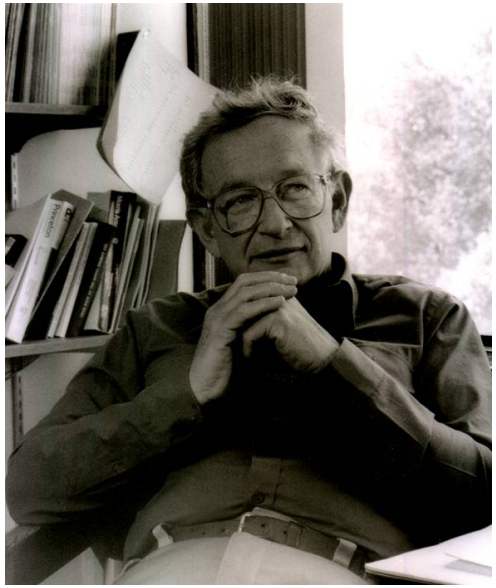
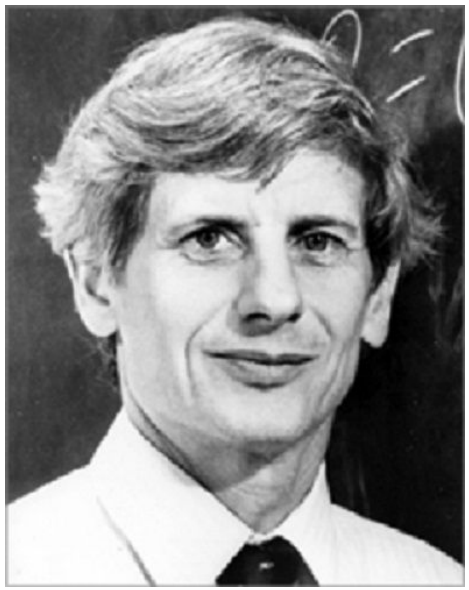
Formalism: symmetries fluctuation theorems

Impurity motion

C. Aron, L. Foini, J. Bonart, A. Tartaglia also L. Ioffe & L. Faoro

Statistical Physics

What is it ?

Phase transitions

Symmetry breaking

Higgs Mechanism

Localisation & SG

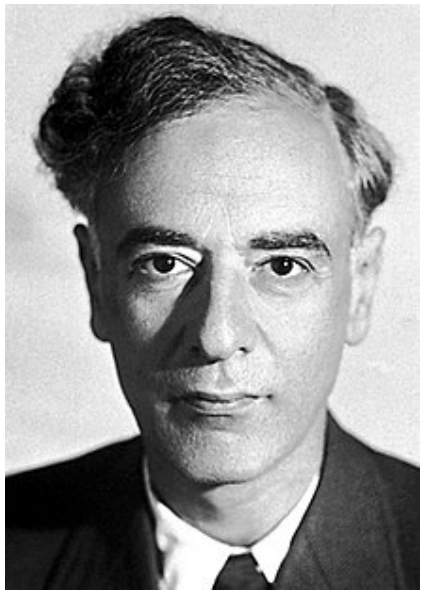
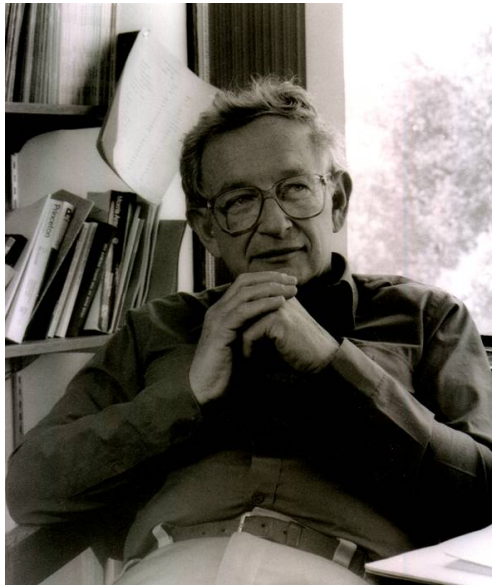
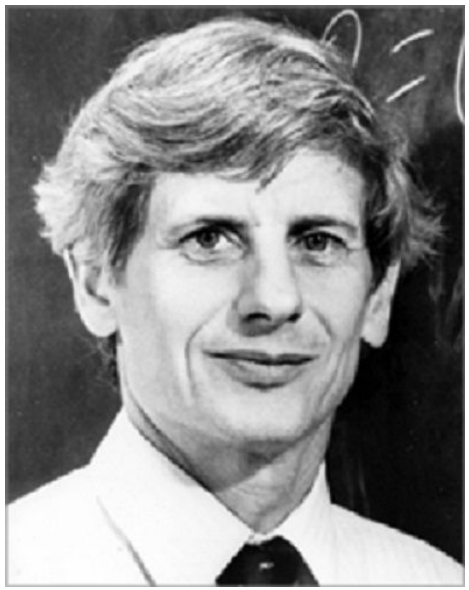
Topology

Spin-glasses

More is different

Statistical Physics

What is it ?

Phase transitions

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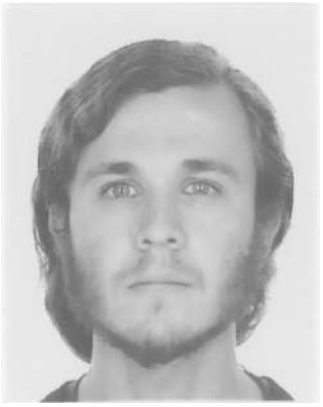
Touche-à-tout

The future

Some students from the group



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