C.I.M.E. Session on "Dirichlet Forms"

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FONDAZIONE C.I.M.E.
CENTRO INTERNAZIONALE MATEMATICO ESTIVO
INTERNATIONAL MATHEMATICAL SUMMER CENTER

"Integrable Systems and Quantum Groups"

is the subject of the First 1993 C.I.M.E. Session.

The Session, sponsored by the Consiglio Nazionale delle Ricerche and by the Ministero dell'Università e della Ricerca Scientifica e Tecnologica, will take place under the scientific direction of Professors Mauro FRANCAVIGLIA (Università di Torino), Silvio GRECO (Politecnico di Torino), Franco MAGRI (Università di Milano) at Villa "La Querceta", Montecatini Terme (Pistoia), **from June 14 to June 22, 1993.**

Courses

a) **Spectral covers, algebraically completely integrable Hamiltonian systems, and moduli of bundles.** (6 lectures in English)
Prof. Ron DONAGI (University of Pennsylvania)

Outline

Spectral covers allow a uniform treatment of a wide variety of algebraically completely integrable Hamiltonian systems, ranging from classical systems such as Jacobi's geodesic flow on an ellipsoid, to recent ones such as Hitchin's commuting flows on the cotangent bundle to the moduli space of stable vector bundles on a curve [H1], and Treibich-Verdier's theory of elliptic solitons [TV]. Our goal is to present an outline of this theory, together with some of the important special cases and applications. Topics to be discussed include:

. Construction of spectral covers, isotypic decomposition of their Picard varieties into generalized Pryms, the distinguished Prym [D2] and its modular interpretation via principal bundles with twisted endomorphisms (generalized 'Higgs bundles'). Kanev's Prym-Tyurin varieties [K] and the n-gonal constructions in Prym theory [D1], the structure of nilpotent cones [L] and its relation with fibers of the Springer resolution.

. Existence of symplectic and Poisson structures, considered both from the modular point of view (following [Ma], [Mu], [T]) and via their infinitesimal cubic invariant (compare [BG]).

. Existence of Lax structures linearizing a given system via spectral covers, and Griffiths' cohomological criterion for linearization [G].

. Examples and applications include:

- Jacobi's system and its generalizations by Beauville and by Adams, Harnad, Hurtubise and Previato.
- Elliptic (and abelian) solitons.
- Hitchin's system for an arbitrary reductive group, with its various applications to the structure of moduli spaces [H1] and to the projectively flat connection in Conformal Field Theory [H2].
- Some non-linear variants of Higgs bundles, living on Mukai spaces.

References

[BG] R. Bryant and P.A. Griffiths, Some observations on the infinitesimal period relations for regular threefolds with trivial canonical bundle, in: Arithmetic and Geometry II, Birkhäuser (1983), 77-102.

[D1] R. Donagi, The tetragonal construction, Bull. AMS 4 (1981), 181-185.

[D2] R. Donagi, Spectral covers, preprint, 1983.

[G] P.A. Griffiths, Linearizing flows and a cohomological interpretation of Lax equations, Amer. J. Math. 107 (1985), 1445-1484.

[H1] N. Hitchin, Stable bundles and integrable systems, Duke Math. J. 54 (1987), 91-114.

[H2] N. Hitchin, Flat connections and geometric quantization, Comm. Math. Phys. 131 (1990), 347-380.

[K] V. Kanev, Spectral curves, simple Lie algebras, and Prym-Tyurin varieties, Proc. Symp. Pure Math. 49 (1989, 627-645.
[L] G. Laumon, Un analogue global du cone nilpotent, Duke Math. J. 57 (1988), 647-671.
[Ma] E. Markman, Spectral curves and integrable systems, UPenn dissertation, 1992.
[Mu] S. Mukai Symplectic structure of the moduli space of sheaves on an abelian or K3 surface, Inv. Math. 77 (1984), 101-116.
[TV] A. Treibich and J.L. Verdier, Solitons elliptiques, The Grothendieck Festschrift, vol. 3, Birkhäuser (1990), 437-480.
[T] A. Tyurin, Symplectic structure on the varieties of moduli of vector bundles on an algebraic surface with p,g>0, Math. USSR Izv. 33 (1989), 139-117.

b) **Geometry of two-dimensional topological field theories.** (6 lectures in English).
Prof. Boris DUBROVIN (Moscow State University and SISSA, Trieste)

Lecture plan

1) Topological symmetric lagrangians and their quantization. Atiyah's axioms of a topological field theory (TFT). Intersection theory on moduli spaces as example of TFT. Topological conformal field theories (TCFT) as twisted N=2 susy theories. Topological deformations of a TCFT.

2) Equations of associativity of the primary chiral algebra as defining relations of a 2D TFT. Differential geometry of the small phase space of a TFT. Classification of massive TCFT by isomonodromy deformation method.

3) Integrable hierarchies associated with arbitrary 2D TFT, their hamiltonian formalism, solutions, and tau-functions. Coupling to topological gravity.

4) Ground state metric as a hermitian metric on the small phase space of a 2D TFT. Calculation of the ground state metric of a massive TCFT by isomonodromy deformations method. Relation to the theory of harmonic maps.

References

1. E. Witten, Surv. Diff. Geom. 1 (1991), 243.
2. R. Dijkgraaf, Intersection theory, integrable hierarchies, and topological field theory. Preprint IASSNS-HEP-91/91, to appear in the Proceedings of the Cargese Summer School on New Symmetry Principles in Quantum Field Theory (1991).
3. B. Dubrovin, Nucl. Phys. B379 (1992), 627.
4. B. Dubrovin, Integrable systems and classification of two-dimensional topological field theories, Preprint SISSA 162/92/FM, Semptember 1992, to appear in the J.-L. Verdier memorial volume, Integrable systems, 1992.
5. B. Dubrovin, Geometry and integrability of topological-antitopological fusion, Preprint INFN-8/92, April 1992, to appear in Comm. Math. Phys.

c) **Integrals of motion as cohomology classes.**. (6 lectures in English).
Prof.Edward FRENKEL (Harvard University)

Outline

Integrals of motion of Toda field theory can be interpreted as cohomology classes. For the classical theory they are cohomology classes of the nilpotent subalgebra of the corresponding finite-dimensional or affine Kac-Moody algebra. For the quantum theory they are cohomology classes of the quantized universal enveloping algebra of the nilpotent subalgebra. This definition makes possible to prove the existence of "big" algebras of integrals of motion in these theories, associated to finite-dimensional Lie algebras, these algebras are nothing but the W-algebras. For the affine Toda field theories, these algebras constitute infinite-dimensional abelian subalgebras of the W-algebras, and they are algebras of integrals of motion of certain deformations of conformal field theories.

References

- B. Feigin, E. Frenkel, Phys. Lett. B 276 (1992), 79-86.
- B. Feigin, E. Frenkel, Int. J. Mod. Phys. 7 (1992), Supplement 1A, 197-215.

d) **Integrable equations and moduli of curves and vector bundles.** (6 lectures in English)
Prof.Emma PREVIATO (Boston University)

Description

The theory of integrable systems/integrable equations of KdV type brought about profound interactions between physics and algebraic geometry over the past twenty years. This course will be an illustration of roughly three areas in the field and of open directions branching out of them: area one, the linearization of certain Hamiltonian flows over Jacobian varieties and generalizations to moduli spaces of vector bundles; two, moduli of special (elliptic) solutions; three, projective realizations of moduli spaces of vector bundles.
A list of topics follows.

Prerequisites

Classical Riemann-surface theory and rudiments of algebraic geometry.

Lecture I	:	Burchnall-Cauchy-Krichever map [ADCKP]
Lecture II	:	Generalization to vector bundles [KN]
Lecture II	:	The elliptic case [K], [M]
Lecture IV	:	The hyperelliptic case [VG]
Lecture V	:	The two-theta map [B]
Lecture VI	:	Verlinde formulas and Kummer varieties [vGP]

References

[ADCKP] E. Arbarello, C. De Concini, V.G. Kac and C. Procesi, Moduli spaces of curves and representation theory, Comm. Math. Phys. 117 (1988), 1-36.

[B] A. Beauville, Fibres de rang 2 sur une courbe, fibre determinant et fonctions theta, II, Bull. Soc. Math. France 119 (1991), 259-291.

[vG] B. van Geemen, Schottky-Jung relations and vector bundles hyperelliptic curves, Math. Ann. 281 (1988), 431-449.

[vGP] B. van Geemen and E. Previato, Prym varieties and the Verlinde formula, Math. Ann. (1933).

[K] I.M. Krichever, Elliptic solutions of the Kadomtsev-Petviashvili equation and integrable systems of particles, Functional Anal. Appl. 14 (1980), 282-290.

[KN] I.M. Krichever and S.P. Novikov, Holomorphic fiberings and nonlinear equations, Finite zone solutions of rank 2, Sov. Math. Dokl. 20 (1979), 650-654.

[M] O.I. Mokhov, Commuting differential operators of rank 3, and nonlinear differential equations, Math. USSR Izvestiya, 35 (1990), 629-655.

FONDAZIONE C.I.M.E.
CENTRO INTERNAZIONALE MATEMATICO ESTIVO
INTERNATIONAL MATHEMATICAL SUMMER CENTER

"Algebraic Cycles and Hodge Theories"

is the subject of the Second 1993 C.I.M.E. Session.

The Session, sponsored by the Consiglio Nazionale delle Ricerche and by the Ministero dell'Università e della Ricerca Scientifica e Tecnologica, will take place under the scientific direction of Prof. Fabio BARDELLI (Università di Pisa) at Villa Gualino, Torino, Italy, **from June 21 to June 29, 1993.**

Courses

a) **Infinitesimal methods in Hodge theory.** (8 lectures in English)
Prof. Mark GREEN (University of California, Los Angeles)

Lecture plan

1) The Hodge Theorem. Hodge decomposition and filtrations. The operators L, Λ and H, and the Hodge identities. Principle of two types. Degeneration of the Hodge-De Rham spectral sequence.

2) The Griffiths intermediate Jacobians, The Abel-Jacobi map. Infinitesimal Abel-Jacobi map and the extension class of the normal bundle sequence. Image of cycles algebraically equivalent to zero under the Abel-Jacobi map.

3) Variation of Hodge structure. The Hodge filtration varies analytically. The period map and its derivative. Infinitesimal period relations (Griffiths transversality). Griffiths computation of the infinitesimal period map as a cup product.

4) Hodge theory of hypersurfaces and complete intersections. Derivative of the period map for hypersurfaces. Infinitesimal Torelli for hypersurfaces and complete intersections. Examples of Hodge classes of cycles on hypersurfaces.

5) Mixed Hodge structures. Examples of extension classes.

6) Normal functions. Normal function associated to a primitive Deligne class. Analyticity and infinitesimal relation for normal functions. Infinitesimal invariant of normal function.

7) Koszul cohomology techniques in Hodge theory. Macaulay-Gotzmann theorem. Codimension of the Noether-Lefschetz locus for surfaces. Donagi's generic Torelli theorem for hypersurfaces. Vanishing of the infinitesimal invariant of normal functions for hypersurfaces of high degree.

8) Further applications of Koszul techniques. Nori's connectedness theorem. Abel-Jacobi map for general 3-fold of degree$\geq$ 6. Surjectivity of the general restriction map for rational Deligne cohomology, and the Poincaré-Lefschetz-Griffiths approach to the Hodge conjecture.

Suggested reading

- P. Griffiths and J. Harris, Principles of Algebraic Geometry, Chapters 0-1. This is a good source for the basic facts of Hodge theory, e.g. lecture 1.
- P. Griffiths, Topics in Transcendental Algebraic Geometry. The chapters (by various authors) include some useful surveys as well as more specialized research articles. Chapters I, III, XII, XIII, XIV, XVI, and XVII are probably the most helpful for this course.
- J. Carlson, M. Green, P. Griffiths, J. Harris, "Infinitesimal Variation of Hodge Structure", I-III. Compositio Math. 50 (1083), 109-

324. These contain a lot of information, including of course many interesting topics that won't be covered in these courses. Worth dipping into.
- M. Green, "Koszul cohomology and geometry", in "Lecture on Riemann Surfaces", Proceedings of the ICTP College on Riemann Surfaces, World Scientific 1989. This represents my best effort at an elementary exposition of the Hodge theory of hypersurfaces and Koszul-theoretic techniques. Sections 1,2 and 4 are relevant.
- M. Cornalba and P. Griffiths, "Some transcendental aspects of algebraic geometry" in "Algebraic Geometry - Arcata 1974", Proc. Symp. in Pure Math. 9, AMS (1975), 3-110. This has a relatively painless introduction to mixed Hodge structures. These lectures mostly deal with the differential-geometric aspects of the period map, a beautiful aspect of Hodge theory that we won't cover.
- J. Carlson and C. Peters have a new book on Hodge theory in the works. If it is available in time, it should be an outstanding introduction to many of the topics to be covered.

b) **Algebraic cycles and algebraic aspects of cohomology and K-theory.** (6 lectures in English).
Prof. Jacob MURRE (Universiteit Leiden)

The following subjects will be discussed:

1) Algebraic cycles.
Basic notions. Discussion of the most important equivalence relations. The Chow ring. The Griffiths group. Statement of the principal known facts in codimension greater than one. The definition of higher Chow groups of Bloch. Definition and main properties of Chern classes of vector bundles. The Grothendieck group of vector bundles and sheaves, and its relation to the Chow groups.

2) Deligne-Beilinson cohomology.
Definition and main properties. Examples. Construction of the cycle map; its relation to the classical cycle map and the Abel-Jacobi map.

3) Algebraic cycles and algebraic K-theory.
Introduction to algebraic K-theory. The functors K_0 (see also 1.), K_1 and K_2. The Bloch formula for the Chow groups. Discussion of the regulator map for $K_2(X)$ when X is an algebraic curve.

4) The Hodge Conjecture.
Statement of the (p,p)-conjecture. Survey of the typical known cases. Discussion of some examples. Statement of the generalized Hodge-conjecture as corrected by Grothendieck. Discussion of an example of Bardelli.

5) Some results in codimension 2.
   a. Applications of the Merkurjev-Suslin theorem of algebraic K-theory.
   b. Incidence equivalence and its relation to Abel-Jacobi equivalence.

6) Introduction to motives.
The standard conjectures and something about motives.

References

1. Bloch, S.: Lectures on algebraic cycles. Duke Univ. Math. Ser. IV, 1980.
2. Fulton, W.: Intersection theory. Erg. der Math., 3 Folge, Bd. 2, Springer Verlag, 1984.
3. Esnault, H. and Viehweg, E.: Deligne-Beilinson Cohomology. In: "Beilinson's conjectures and special values of L-function". Perspectives in Math., Vol. 4, Academic Press 1988.
4. Shioda, T.: What is known about the Hodge conjecture? In: Advances Studies in Pure Math., Vol. 1 Kinokuniya Comp. and North Holland, Tokyo 1983.
5. Murre, J.P.: Applications of algebraic K-theory to algebraic geometry. Proc. Conf. Alg. Geom. Sitges 1983, Springer LNM 1124.

c) **Transcendental methods in the study of algebraic cycles.** (8 lectures in English).
Prof. Claire VOISIN (Université de Orsay, Paris)

Outline of the lectures

1) Divisors.
Weil divisors. Cartiers divisors and line bundles; rational and linear equivalence; GAGA principle. The exponential exact sequence and its consequences:

- homological equivalence=algebraic equivalence for divisors
- the Lefschetz theorem on (1,1) classes; Neron-Severi group
- Hodge structure on H^1 and abelian varieties: the Picard variety
- the existence of Poincaré divisor

2) Topology and Hodge theory
Morse theory on affine varieties and the weak Lefschetz theorem. The Hodge index theorem. Consequences: The hard Lefschetz theorem and the Lefschetz decomposition. Applications:
- reduction to the primitive middle dimensional cohomology; degeneracy of Leray spectral sequences; semi-simplicity of the category of polarized Hodge structures.

3) Noether-Lefschetz locus
Deformations of Hodge classes. The Noether-Lefschetz loci; algebraicity of the components; local study (application of transversality of the period map to the codimension, infinitesimal description). Relation with the deformation theory of cycles; ghe semi-regularity property and Bloch-Kodaira theorem.

4) Monodromy
Nodal varieties. Lefschetz degenerations and Lefschetz pencils. Vanishing cycles and cones over them. The Picard-Lefschetz formula and applications of Noether-Lefschetz type. Discussion of the Hodge theory of the vanishing cycles on the central fibre.

5) O-cycles I
O-cycles and holomorphic forms on varieties; Mumford's theorem on the infinite dimensionality of the CH_0 group. Roitman's theorem: CH^0_0 finite dimensional $\Leftrightarrow$ $CH^0_0 \cong$ Alb. The Bloch's conjecture for surfaces and Bloch-Kas-Lieberman theorem.

6) O-cycles II
The proof of the Bloch conjecture for Godeaux type surfaces; Bloch-Srinivas theorem and consequences of "CH_0 small" on algebraic cycles and Hodge theory of a variety.

7) Griffiths group
One cycles on threefolds; Abel-Jacobi map on cycles algebraically equivalent to zero. Normal functions and their Hodge classes: The theorem of Griffiths. Statement of Clemens theorem and further examples.

8) Application of the NL locus to threefolds
M. Green's criterion for density of the Noether-Lefschetz locus. Applications to one-cycles on threefolds:
- parametrization of certain sub-Hodge structures by algebraic cycles
- infinitesimal proof of Clemens theorem
- generalization of Griffiths theorem to any Calabi-Yau threefold

References

- A. Weil: Variétés Kahleriennes, Actualités scientifiques et industrielles.
- J. Milnor: Morse theory, Annals of Math. Studies, Study 21, Princeton Univ. Press.
- Carlson, Green, Griffiths, Harris: Compositio Math. Vol. 50 (three articles).
- P. Deligne: Théorie de Hodge II, I.H.E.S. Publ. Math. 40, (1971), 5-58.
- P. Griffiths: On the periods of certain rational integrals I, II, Ann. of Math. 90 (1969), 460-541.
- P. Griffiths: Topics in transcendental algebraic geometry, Annals of Math. Studies, Study 106, Princeton Univ. Press.
- H. Clemens: Double solids, Advances in Math. Vol. 47 (1983).

FONDAZIONE C.I.M.E
CENTRO INTERNAZIONALE MATEMATICO ESTIVO
INTERNATIONAL MATHEMATICAL SUMMER CENTER

"Modelling and Analysis of Phase Transition and Hysteresis Phenomena"

is the subject of the Third 1993 C.I.M.E. Session.

The Session, sponsored by the Consiglio Nazionale delle Ricerche and by the Ministero dell'Università e della Ricerca Scientifica e Tecnologica, will take place under the scientific direction of Prof. Augusto VISINTIN (Università di Trento) at Villa "La Querceta", Montecatini Terme (Pistoia), **from July 13 to July 21, 1993.**

Courses

a) **Hysteresis operators.** (6 lectures in English)
Prof. Martin BROKATE (Universität Kaiserslautern)

Course outline

1) Scalar hysteresis operators.
Example of hysteresis models. Hysteresis operators. Continuity properties. Memory properties. Applications.

2) Vector hysteresis operators

3) Hysteresis operators and differential equations.
Ordinary differential equations with hysteresis. Parabolic equations with hysteresis. Hyperbolic equations with hysteresis. Shape memory alloys. Control problems with hysteresis.

References

1. Books:
   - Brokate, M.: Optimal control of ordinary differential equations with nonlinearities of hysteresis type. Peter Lang Verlag, Frankfurt 1987. (In German; English translation in: Automation and Remote Control, 52 (1991) and 53 (1992)).
   - Krasnoselskii, M.A., Pokrovskii, A.V.: Systems with hysteresis. Springer 1969.
   - Mayergoyz, I.D.: Mathematical models of hysteresis. Springer 1991.
2. Survey:
   - Visintin, A.: Mathematical models of hysteresis. In: Topics in nonsmooth mechanics (eds. J. J. Moreau, P.D. Panagiotopoulos, G. Strang), Birkhäuser 1988, 295-326.
3. Papers:
   - Brokate, M., Visintin, A.: Properties of the Preisach model for hysteresis, J. Reine Angew. Math. 402 (1989), 1-40.
   - Krejcí, P.: A Monotonicity method for solving hyperbolic problems with hysteresis. Apl. Mat. 33 (1988), 197-203.
   - Krejcí, P.: Hysteresis memory preserving operators. Applications of Math. 36 (1991), 305-326.
   - Krejcí, P.: Vector hysteresis models. European J. Appl. Math. 22 (1991), 281-292.
   - Visintin, A.: A model for hysteresis of distributed systems. Ann. Mat. Pura Appl. 131 (1982), 203-231.
   - Visintin, A.: Rheological models and hysteresis effects. Rend. Sem. Mat. Univ. Padova 77 (1987), 213-243.

b) **Systems of nonlinear PDEs arising from dynamical phase transition.** (6 lectures in English).
Prof. Nobuyuki KENMOCHI (Chiba University)

Outline of the contents

Systems of nonlinear PDEs are proposed as mathematical models for thermodynamical phase transition processes such as solidification and melting in solid-liquid systems. These are nonlinear parabolic PDEs and variational inequalities with obstacles and the unknowns are the absolute temperature and the order parameter representing the physical situation of the materials. We analyze these models from the following points (1)-(4) of view:

(1) Physical background of the problem
(2) Abstract treatment of the problem
(3) Existence and uniqueness results
(4) Asymptotic stability for the solutions

The basic literature references for the subjects

Nonlinear PDEs:

- D. Gilbarg and N. S. Trudinger, Elliptic Partial Differential Equations of Second Order, Springer-Verlag, Berlin, 1983.
- H. Brézis, Problémes unilatéraux, J. Math. pures appl., 51 (1972), 1-168.

Convex Analysis:

- J. L. Lions, Quelques méthodes de résolution des problémes aux limites non linéaires, Dunod, Gauthier-Villars, Paris, 1969.
- H. Brézis, Opérateurs maximaux monotones et semi-groupes de contractions dans les espaces de Hilbert, North-Holland, Amsterdam, 1973.

c) **Quasiplasticity and Pseudoelasticity in Shape Memory Alloys.** (6 lectures in English).
Prof. Ingo MÜLLER (Technical University Berlin)

Course outline

1. Phenomena.
The phenomena of quasiplasticity and pseudoelasticity in shape memory alloys are described and documented. They are due to a martensitic-austenitic phase transition and to the twinning of the martensitic phase, which is the lowtemperature phase.

2. Model.
A strctural model is introduced wihich is capable of simulating the observed phenomena. The model consists of lattice layers in a potential which has three potential wells, one metastable. Adjacent layers are coherent and their formation requires an extra energy, the coherency energy.

3. Statistical Mechanics.
Statistical Mechanics of the model provides a non-convex free energy and - consequently - a nonmonotone load deformation curve. This is appropriate for pseudoelasticiy. The proper description of quasiplasticity requires a kinetic theory of the model, akin to the theory of activated processes in chemistry.

4. Hysteresis.
Minimization of the free energy under constant deformation leads us to conclude that the observed hysteresis in the pseudo-elastic range is due to the coherency energy. The phase equilibria are unstable and this explains the occurence of internal yield and recovery in pseudoelasticity. A simple mathematical construct for the non-convex free energy permits the description of many observed phenomena inside the hysteresis loop.

5. Thermodynamics.
A systematic exploitation of the first and second law of thermodynamics allows us to predict the thermal and caloric side effects of pseudoelastic deformation.

6. Metastability.
The nature of the metastable states inside the hysteresis loop is as yet not well understood. But there are partial results. They concern observations of the number of interfaces during the phase transition and the role of a "fluctuation temperature" which activates the body to the extent that its entropy can approach its maximum value.

d) **Variational methods in the Stefan problem.** (6 lectures in English)
Prof. José Francisco RODRIGUES (CMAF/Universidade de Lisboa)

Outline of contents

The Stefan problem is one of the simplest possible macroscopic models for phase changes in a pure material when they occur either by heat conduction or diffusion. Its history provides a helpful example of the interplay between free boundary problems and the real world. This course intends to introduce this model problem and to develop an exposition of the variational methods applied to the study of weak solutions for multidimensional problems.

Plan:

1. Introduction to the mathematical-physics models
2. Analysis of the one-phase problem via variational inequalities I
3. Analysis of the two-phase problem via variational inequalities II
4. Study of the enthalpy formulation via Galerkin method
5. Analysis of more complex Stefan problems

Some basic literature

1. G. Duvaut & J. L. Lions, Les inéquations en mécanique et en physique, Dunod, Paris, 1972 (English transl. Springer, Berlin, 1976).
2. A. Friedman, Variational principles and free boundary value problems, Wiley, New York, 1982.
3. D. Kinderlehrer & G. Stampacchia, An introduction to variational inequalities and their application, Academic Press, New York, 1980.
4. J. L. Lions, Sur quelques questions d'analyse, de mécanique et de control optimal, Press Univ. Montréal, 1976.
5. A. M. Mermanov, The Stefan problem, W. De Gruyter, Berlin, 1992.
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e) **Numerical aspects of free boundary and hysteresis problems.** (6 lectures in English).
Prof. Claudio VERDI (Università di Pavia)

Summary

1. Time discretization of strongly nonlinear parabolic equations
   - 1.1 Nonlinear methods
   - 1.2 Linear methods
   - 1.3 Applications to problem with hysteresis

2. Full discretization
   - 2.1 Finite element spaces
   - 2.2 Nonlinear schemes
   - 2.3 Linear schemes
   - 2.4 Stability of fully discrete schemes
   - 2.5 Error estimates
   - 2.6 Approximation of free boundaries

3. Adaptive finite element methods for parabolic free boundary problems

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