ESF-EMS-CRM-Pi

International Conference on

Knots and Links: From Form to Function

Centro di Ricerca Matematica (CRM) "Ennio De Giorgi"
Scuola Normale Superiore – Pisa, Italy

2-8 July, 2011

http://www.esf.org/conferences/11379

HIGHLIGHTS and SCIENTIFIC REPORT

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Conference Highlights

The international conference on *Knots and Links: From Form to Function* has been held at the "Ennio De Giorgi" Mathematical Research Centre (CRM) of the Scuola Normale Superiore of Pisa on 2-8 July, 2011. This conference has been an event of primary importance in the mathematical sciences, providing an international forum of extremely high level at the crossroad of geometric knot theory, mathematical and theoretical physics, classical physics and biology. More than 80 specialists, nearly 30 of which world leaders in their own field, convened from as disparate countries as several EU members states, USA, Russia, Japan, Arab countries, Africa and China. The inderdisciplinary nature of the conference provided a unique opportunity for mathematicians and mathematical scientists to promote and enhance cross-fertilization of new ideas and techniques, from pure to applied mathematics, numerical modeling, physics and biology. New results on geometric, numerical and visualization knot theory have been presented to explore open problems in classification issues, energy/complexity relations, minimal energy states, knot tightening and ideal shapes, as well as to investigate fundamental questions in modern topological field theory, condensed matter physics, chemical physics and DNA biology. Keynote lectures outlined the progress made, identifying the new challenges ahead; regular lectures, short communications and posters were presented in almost all fields of science. Mathematical and physical knots, links and braids provided the natural, recurrent theme throughout the conference and mathematics the common language. From the imaginary and abstract world of pure mathematics to the realm of intricate microstructures in genomics the role of form, in the shape of mathematical and physical knots, has been investigated in relation to its possible function, one of the key problems at the core of modern research in applied sciences.

The conference was chaired by Professor Renzo Ricca (U. Milano-Bicocca), a world expert in topological field theory, and co-chaired by Professor De Witt Sumners (Florida State U.), an authority in mathematical biology and DNA knots. Pure mathematicians such as Kenneth Millett (UC Santa Barbara), Carlo Petronio (U. Pisa), Colin Adams (Williams College), Robert Kusner (U. Massachusetts), John Sullivan (Technical U. Berlin), Jun O'Hara (Tokyo Metropolitan U.), applied mathematicians such as Keith Moffatt (U. Cambridge), Dorothy Buck (Imperial College London), Carlo Barenghi (U. Newcastle-upon-Tyne) and software developers such as Robert Scharein (Hypnagogic Software) and Piotr Pieranski (Poznan U. Technology) engaged in lively discussions with reknown physicists such as Thomas Kephart (Vanderbilt U.) and Giovanni Dietler (EPFL), theoretical physicists such as Bertrand Duplantier (CEA, Saclay), Michael Monastyrskii (ITEP, Moscow), Enore Guadagnini (U. Pisa), and biologists such as Andrew Stasiak (U. Lausanne) and Javier Arsuaga (San Francisco State U.). Even a professional magician, like Fernando Blasco (U. Politécnica Madrid), entertained the audience in a very amusing show-presentation. A conference dinner in the splendid former monastery of Santa Croce in Fossabanda, an excursion to the nearby Tuscany village of San Miniato, and a wine-tasting at San Quintino farmhouse, contributed to have made this event a memorable one.

✔ I hereby authorize ESF – and the conference partners to use the information contained in the above section on 'Conference Highlights' in their communication on the scheme.

Scientific Report

Executive Summary

(2 pages max)

This conference was held at the "Ennio De Giorgi" Mathematical Research Centre (CRM) in Pisa, which is one of the ERCOM centres of ESF. The conference programme followed strictly what was outlined and planned in the proposal and it was held starting on Sunday July 2 and ended on Friday morning, July 8, 2011. As usual, the organization involved work on logistic, scientific and social aspects. Staff from CRM (Ms. Caterina D'Elia) and ESF (Ms. Anne Guehl) provided invaluable support and assistance to this Chair, all along the whole process. From the logistic viewpoint Ms. D'Elia provided help to identify and select suitable accommodation and lecture room for the participants, by taking advantage of the facilities of the Scuola Normale Superiore (SNS), and working in close collaboration with Ms. Guehl, giving advice and monitoring the allocation of budget. All budget was spent according to ESF guidelines, towards accommodation costs, partial support of young participants and travel grants. The Chair, Ms D'Elia and Ms. Guehl worked in perfect collaboration and symbiosis.

Logistics. Detailed information on local travel and hotel arraengements were given prior to the conference by e-mail and at the beginning of the conference and by distributing ESF folders with printed material to each participant. Most of the participants were accommodated in a charming former monastery (Santa Chiara di Fossabanda) converted into a 3 star hotel, at a pleasant walking distance from the old town centre, the CRM and the lecture room. Some of the most senior and aged lecturers were lodged at the CRM "foresteria" (in Piazza dei Cavalieri), which provided comfortable rooms and basic facilities to the guests. Office desks, laptops and internet connection were provided to some of the participants and Chairs for daily work at CRM plus additional meeting rooms and space to all participants. All meals were served at the SNS canteen by access card and all lectures were held in the lecture room "Aula Dini", both facilities a stroll away from each other and from CRM. The lecture room was large and adequate, equipped with all modern facilities and services, including internet access. An ESF desk was also set up outside the room for additional help. The close vicinity of all these facilities, located in the heart of the old town, were key to a successful and efficient arrangement of all the activities.

Scientific organization. The scientific organization relied on the preliminary work done by this Chair in the selection of the keynote participants. Scientific excellence and interdisciplinarity were the criteria followed during this stage. A second selection process took place on the list of submitted applications made by mid-career scientists and young researchers. Here particular attention was paid to promote the participation of young researchers, also as regards gender balance and nationality, which represents often a difficult task in the mathematical sciences. Overall, I think both these points were also satisfactorily achieved. The scientific programme consisted of invited and normal lectures as well as short oral presentations. a poster session, and a "Forward Look Plenary Discussion" session (video recorded) on open problems and future challenges in the field (see Scientific Content of the Conference, here below).

Social programme. Since the social programme represents often an important and integral part of a successful conference, much attention was paid to this part. Coffee breaks took place on every mid-morning and mid-afternoon, from Sunday to Thursday, and lasted 15 minutes each. Nearly one hour of free time was left after lunch and before dinner, every day, for discussion and socializing. A drink party followed by a conference dinner was organized in the beautiful court garden and portico of the hotel Fossabanda on Tuesday evening, and an afternoon excursion to visit the nearby old village of San Miniato together with a wine tasting in the vineyards of the San Quintino farmhouse took plane on Wednesday. Finally, to mark the end of the conference proceedings, a one hour show-presentation was

organized on Thursday evening by a professional magician (and mathematician!). This took place in the beautiful, old “Aula degli Stemmi” lecture room of SNS, where the magician entertained and engaged members of the audience with tricks and humor.

The sunny weather and the friendly atmosphere of this contributed to have made this conference a memorable event. This was confirmed by the standing ovation that all participants decide to tribute to this Chair, its organizers and sponsors.

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Knots and Links: From Form To Function

Centro di Ricerca Matematica (CRM) "Ennio De Giorgi" - Scuola Normale Superiore - Pisa (Italy)

2-8 July, 2011

A moment of the show-presentation *Mathematical magic with knots* by Professor Fernando Blasco (center).

Scientific Content of the Conference

(1 page min.)

Summary of the conference sessions.

The conference proceedings started on Sunday 2 July, at 10:30 am and ended on Thursday 7 July at 10:30 pm. There were no parallel sessions and all morning and afternoon sessions were structured in invited lectures of 40 mins. (including 5 minute question time), followed by shorter lectures of 20 mins. (including 5 minute question time). A poster session was organized on Tuesday 5 July at 7:00 pm, and 5 minutes were allocated to each poster author for an oral presentation of the poster content on Tuesday morning. A "Forward Look Plenary Discussion" session concluded the conference on Thursday evening. About 80 speakers, leaders in their own field, gathered from all over the world to deliver their lectures and Chairs made sure that times allocated were strictly adhered to, thus guaranteeing a smooth run of the proceedings. The conference programme is reproduced here below.

PROGRAMME

SUNDAY, JULY 3

9:00 – 10:00 Registration at the ESF desk – CRM, Collegio Puteano

Sunday morning (Chair: R. Ricca)

10:00 – 10:15 Coffee at "Aula Dini"
10:15 – 10:30 Opening address
10:30 – 11:05 **Keith Moffatt** (University of Cambridge)
Relaxation to topologically complex equilibria
11:10 – 11:45 **De Witt Sumners** (Florida State University)
DNA Topology: experiments and analysis
11:50 – 12:05 **Eugene Starostin** (University College London)
Elastic 2-braids, knots and links
12:10 – 12:25 **Eleni Panagiotou** (National Technical University of Athens)
A study of the linking number in systems with periodic boundary conditions

12:30 – 14:00 Lunch at SNS cafeteria

Sunday afternoon (Chair: E. Rawdon)

14:15 – 14:50 **Yuanan Diao (**University of North Carolina at Charlotte)
Random polygons and random links in a confined volume
14:55 – 15:30 **Nafaa Chbili** (UAEU at Abu Dhabi)
From symmetry of knots to symmetry of spatial graphs
15:35 – 15:50 **Matt Mastin** (University of Georgia)
Link symmetry and composite links
15:55 – 16:10 **Tobias Hermes** (Aachen University)
A gradient flow for Menger curvature
16:15 – 16:35 Coffee break
16:35 – 17:10 **Cristian Micheletti** (SISSA, Trieste)
Geometrical and topological entanglement in ring polymers under spherical confinement
17:15 – 17:50 **Tetsuo Deguchi** (Ochanomizu University)
Random knots and polymer physics
17:55 – 18:10 **Mauro Mauricio** (Imperial College)
An extension of the tangle model for composite knots
18:15 – 18:30 **Simon Candelaresi** (U. Stockholm & NORDITA)
Decay of helical and non-helical magnetic links and knots

MONDAY, JULY 4

Monday morning (Chair: D. Ilyutko)

9:00 – 9:35 **Colin Adams** (Williams College)
Indicatrices, stick index and superinvariants of knots

9:40 – 10:15 **Jun O'Hara** (Tokyo Metropolitan University)
Möbius invariant energies and average linking with circle

10:20 – 10:35 **Simon Blatt** (ETH Zuerich)
The gradient flow of O'Hara's knot energies

10:40 – 11:00 Coffee break

11:00 – 11:35 **Robert Kusner** (U. Pennsylvania & U. Massachusetts)
Knots and links as ropes, bands and branched coverings

11:40 – 12:15 **Eric Rawdon (**University of St. Thomas)
Knotted arcs

12:20 – 12:35 **Philipp Reiter** (U. Freiburg)
Regularity theory for O'Hara's knot energy family E^{α}

12:40 – 14:00 Lunch at SNS cafeteria

Monday afternoon (Chair: T. Deguchi)

14:15 – 14:50 **Carlo Barenghi** (Newcastle University)
Vortex knots and vortex tangles in quantum fluids

14:55 – 15:30 **Enore Guadagnini** (University of Pisa)
Knots and quantum field theory

15:35 – 15:50 **Thomas Kephart** (Vanderbilt University)
The tight knot spectrum in QCD

15:55 – 16:10 **Jose Luis Trueba** (Rey Juan Carlos University)
Some new results on knotted electromagnetic fields in vacuum

16:15 – 16:35 Coffee break

16:35 – 17:10 **Mitchell Berger** (University of Exeter)
The writhe of open curves: theory and applications

17:15 – 17:50 **Xin Liu** (University of Sydney)
Knot polynomials in topological fluid mechanics

17:55 – 18:10 **Rafal Komendarczyk** (Tulane University)
Higher order helicities via link maps

18:15 – 18:30 **Manuel Arrayas** (Rey Juan Carlos University)
Persistence of entanglement and helicity integrals in reaction-diffusion systems

TUESDAY, JULY 5

Tuesday morning (Chair: E. Guadagnini)

9:00 – 9:35 **Bertrand Duplantier (**CEA at Saclay)
Random linking

9:40 – 10:15 **Renzo Ricca** (University of Milano-Bicocca)
On the groundstate energy spectrum of magnetic knots

10:20 – 10:35 **Satoshi Tanda** (Hokkaido University)
Discovery of topological knot and link crystals

10:40 – 11:00 Coffee break

11:00 – 11:35 **Mario Rasetti** (Politecnico di Torino)
Category theory, quantum physics, topology of formal languages and computation

11:40 – 12:30 Poster Presentation (5 mins each)

1.: **Marcin Modlinski** (Poznan University of Technology)
Symmetry of the average shape of the fluctuating trefoil knot

2.: **Piotr Pieranski** (Poznan University of Technology)
Conjectures concerning the curvature and torsion of the ideal trefoil knot

3.: **Sylwester Przybyl** (Poznan University of Technology)
Forces and momenta of forces within the most tight trefoil knot

4.: **Candice Price** (University of Iowa)
A biological application of knot floer homology

5.: **Eleni Panagiotou** (National Technical University of Athens)
A study of entanglement in polymer melts

6.: **Francesca Maggioni** (University of Bergamo)
Optimal kinematics of supercoiled filaments

7.: **Christopher Prior** (University of Oxford)
The Fourier transform of tubular densities

8.: **Toru Matsuura** (Hokkaido University)
Surgery method for ring-shaped crystals

9.: **Lulia Elena Hirica** (University of Bucharest)
On generalized Riemann flow

10.: **Yohannes Sewiye** (University of Jimma)
Structure dictates function, a universal principle that explains the link between human anatomy and physiology

12:40 – 14:00 Lunch at SNS cafeteria

Tuesday afternoon (Chair: Y. Diao)

14:15 – 14:50 **Carlo Petronio** (University of Pisa)
Exceptional Dehn surgeries on the minimally twisted 5-chain link

14:55 – 15:30 **Denis Ilyutko** (Moscow State University)
An equivalence between two theories of `non-realizable' links

15:35 – 15:50 **Gyo Taek Jin** (KAIST)
Prime knots whose arc index is smaller than the crossing number

15:55 – 16:10 **Takahiro Kitayama** (Kyoto University)
On the leading coefficient of the metabelian Alexander polynomial

16:15 – 16:35 Coffee break

16:35 – 17:10 **Sofia Lambropoulou** (National Technical University of Athens)
Framization of knot algebras

17:15 – 17:50 **Annalisa Calini** (College of Charleston)
Integrable evolution of closed vortex filaments: finite-gap solutions and their linear stability

19:00 – 20:00 Poster Session at Hotel Fossabanda

20:00 – 22:00 Conference Dinner at Hotel Fossabanda

WEDNESDAY, JULY 6

Wednesday morning (Chair: R. Kusner)

9:00 – 9:35 **Kenneth Millett** (University of Californa at Santa Barbara)
Measures of polymer shape

9:40 – 10:15 **Jason Cantarella** (University of Georgia)
New computational approaches to exploring polygon and knot spaces

10:20 – 10:35 **Radmila Sazdanovic** (University of Pennsylvania)
Categorification in knot and graph theory

10:40 – 11:00 Coffee break

11:00 – 11:35 **John M. Sullivan** (Technical University of Berlin)
Ropelength criticality

11:40 – 12:15 **Pawel Strzelecki** (University of Warsaw)
Geometric curvature energies for curves: an overview of analytic and knot-theoretic properties

12:20 – 12:35 **Ioannis Diamantis** (National Technical University of Athens)
Toward the 3rd skein module of L(p,q)

12:40 – 14:00 Lunch at SNS cafeteria

Wednesday afternoon

14:00 – 19:00 Social event: visit to the village of San Miniato and wine tasting at the San Quintino farmhouse

THURSDAY, JULY 7

Thursday morning (Chair: J. Cantarella)

9:00 – 9:35 **Mark Dennis** (University of Bristol)
Fibred knots in laser beams

9:40 – 10:15 **Michael Monastyrskii** (ITEP, Moscow)
Topology of ensembles of links and knots and some applications to physics

10:20 – 10:35 **Maria Elena Vazquez** (San Francisco State University)
Modeling DNA unlinking

10:40 – 11:00 Coffee break

11:00 – 11:35 **Andrew Stasiak** (University of Lausanne)
Tightening of DNA knots by supercoiling facilitates their unknotting by type II DNA topoisomerases

11:40 – 12:15 **Isabel Darcy** (University of Iowa)
Tangle analysis of protein-DNA complexes

12:20 – 12:35 **Javier Arsuaga** (San Francisco State University)
The effects of minicircle density on the topological structure of the mitochondrial DNA from trypanosomes

12:40 – 14:00 Lunch at SNS cafeteria

Thursday afternoon (Chair: K. Millett)

14:15 – 14:50 **Robert Scharein** (Hypnagogic Software)
Investigating knots and tangles in physical systems

14:55 – 15:30 **Piotr Pieranski** (Poznan University of Technology)
High resolution picture of the ideal trefoil knot:

new morphology details and new conjectures

15:35 – 15:50 **Igor Nikonov** (Moscow State University)
Parity functors on knot diagrams

15:55 – 16:10 **Marta Szumanska** (University of Warsaw)
Knots with finite integral Menger curvature energy

16:15 – 16:35 Coffee break

16:35 – 17:10 **Giovanni Dietler (**EPFL)
Interplay between topology and bubble formation in double-stranded DNA

17:15 – 17:50 **Dorothy Buck** (Imperial College London)
The classification of rational tangle adjacencies, with applications to complex nucleoprotein assemblies

Thursday evening (Chair: De W. Sumners)

20:45 – 21:00 Gathering at the Scuola Normale Superiore, lecture room "Sala degli Stemmi" (top floor): SNS presentation

21:00 – 21:35 **Fernando Blasco** (Universidad Politécnica de Madrid)
Mathematical magic with knots

21:40 – 22:30 Forward Look Plenary Discussion
Panel: **K. Millett, K. Moffatt, C. Petronio, De W. Sumners**
Moderator: **R. Ricca**
Open problems and future challenges in knot theory and applications

Assessment of the results.

From the scientific viewpoint the conference was extremely successful. Many new and interesting results were presented and discussed openly among the different groups. Emphasis on interdisciplinarity also paid off, by opening up new directions of research and addressing new problems. In pure mathematics new results were presented in hyperbolic geometry, ideal shapes, hierarchical algebraic structures of knot polynomial and in braid theory; the interplay of local geometric features in knot classification issues based on crossing number and ideal shapes emerged as an important aspect of current research. In applied mathematics new results on the energy spectrum of magnetic knots and links were presented as well as on knot tightening techniques and corresponding knot energy. From the computational and applied sciences progress was reported in knot visualization and diagnostics, knots in optics, knotted polymers and DNA knots and tangles. Some of the scientific highlights of the conference were taken up and discussed further in a lively "Forward Look Plenary Discussion" session, that concluded the conference in an atmosphere of general satisfaction and enthusiasm.

Forward Look

(1 page min.)

Assessment of the results.

Without doubt this conference fostered considerable progress in fundamental aspects in geometric knot theory on one hand, and topological dynamics in physical and biological sciences on the other. The gathering of people with different background and expertise, but with common interest in knot theory, encouraged new collaborations and opened up new research themes at the forefront of modern research. This strategy proved successful for crossfertilization between fields and confirmed that this effort should be pursued further in the foreseeable future. Work on geometric aspects, from global and local viewpoint, proved very fruitful for both classification purposes and applications: in this context particularly relevant was new work presented on relationships between crossing number and ropelength, and ideal shape of knots and their topological classification. In theory, numerical simulations and experiments the role played by the hierarchical organization of mathematical and physical structures became evident: this emerged from current work on the algebraic structures of knot polynomials and it was echoed by the structural complexity of filamentary structures observed in chemical physics and biology. Important progress was made in the context of topological classification of physical energy groundstates, both in topological quantum field theory and in classical physics. Discussion on energy spectra of various origin evidenced common features rooted in ropelength analysis, enforcing the bridge between geometric knot theory and foundational aspects of physical field theory. In biological sciences new results on DNA knot formation in viral capsids and human cells were reported, opening up new scenarios for future research directions and tools. Very interesting progress was also made in numerical simulation, visualization and diagnostics based on knot theoretical information. Very detailed studies on knot tightening revealed how geometric features (such as presence of inflexion points or angular points) might play a crucial role in the ideal shape problem. Advanced visualization of complex structures in vortex dynamics, astrophysics and optics could track information about dynamics and energy useful for applications and new software developed to make real time analysis of numerical or observational data was presented. All these results will be relevant in the nearby future and will be pursued further in modern research.

Contribution to the future direction of the field.

This conference has been seminal in the future crossfertilization of topological issues in knot theory with geometry, physics and biology. As mentioned above, work on ropelength, topological aspects in groundstate energy spectra and hierarchical organization of structures in pure and applied sciences has been seminal to the future direction of the field. New directions in geometric knot theory, numerical visualization and diagnostics, topological dynamics and topological biology have been identified.

Identification of emerging topics.

Topics of particular relevance emerged distinctively.

- Modern techniques of hyperbolic geometry prove very powerful in the search for new topologies and in the construction of new topological invariants. New work on implementation and diagnostics of theoretical concepts is expected.
- Geometric characterization of ideal shapes and ropelength information opens up new frontiers, bridging geometric topology, differential geometry and foundational aspects in field theory, worth exploring; this will entail on one hand a novel approach to the packing problem in 3D, and on the other new progress in a topological approach to potential theory.

- Progress in visualization demonstrates that time is now mature for real-time implementation of knot theoretical concepts in numerical diagnostics (visiometrics) of simulated fluid flows and magnetic fields in turbulence and plasma physics.
- Knot theoretical concepts play an ever increasing role in DNA biology; more and more work on topological biology is expected, especially in the emerging field of tangle analysis, numerical implementation of dedicated software and diagnostic tools for scientific simulations.
- Random knotting and stochastic system analysis prove useful to tackle structural complexity issues in the study of macromolecules and filament networks in polymer physics and complex system physics.

▪ Is there a need for a foresight-type initiative?

The conference proceedings showed the richness and potential of such an interdisciplinary approach, and the importance of the topics discussed evidenced their relevance in their respective particular fields of origin, knot theory, visualization, mathematical fluid mechanics, quantum field theory, polymer physics and DNA biology. In this respect it would be strategically important to strengthen current research on topics covered by this conference by supporting further initiatives in this direction in the near or medium term future.

Business Meeting Outcomes

Election of the Organising Committee of the next conference.
In the light of two major events that will take place in 2012 (see Next Steps) no decision was taken to elect an Organizing Committee for the next conference. However, Professor Sofia Lambropoulou (Technical University of Athens) and the present Chair agreed to act as possible promoters for the next conference. It would be very important to maintain the next initiative in this direction within the ESF flagship.

Identified Topics.
The following topics are identified as particularly important:
- work on ideal shapes and geometric aspects in knot theory;
- topological dynamics in physical and biological sciences;
- DNA knots;
- structural complexity analysis;
- numerical implementation of knot theoretical ideas and visiometrics.

Next Steps.
Two major events of international level, a 4-week workshop on *Physical Knots* at the Kavli Institute for Theoretical Physics (UC Santa Barbara) and a 6-month programme on *Topological Dynamics in the Physical and Biological Sciences* (Isaac Newton Institute for Mathematical Sciences, U. Cambridge) will be held in 2012.

Atmosphere and Infrastructure

Overall the great majority of the participants were happy or very happy about both location and organization, including networking and facilities provided (services, common areas, office space, canteen, accommodation and social activities). The effort made by this Chair to take care of all aspects, including social, paid off: the high quality in science gave an immediate good kick-off to the conference proceedings and the general satisfaction increased as the programme developed. CRM staff and the close vicinity of all the facilities contributed to this success.

issues can be addressed in the next page, which will not be published.

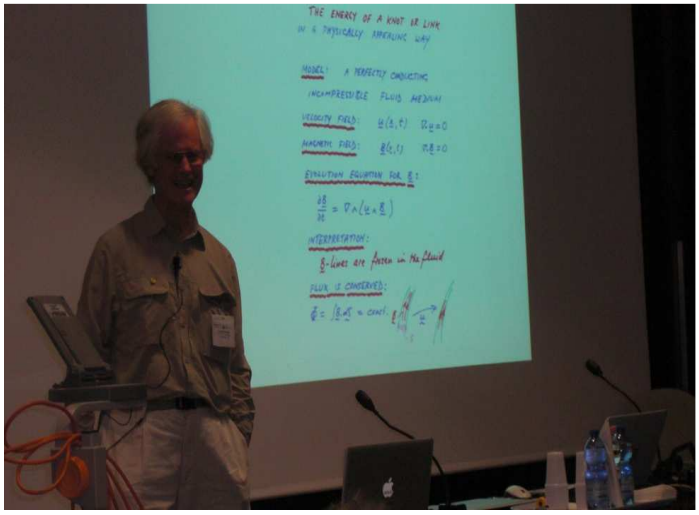
✔ I hereby authorize ESF to publish the information contained in the above Scientific Report on the ESF Research Conferences Webpages. No sensitive or confidential information (see above) has been included in this report

Confidential Issues

There are no confidential issues to report.

Gallery

Professors De Witt Sumners (Co-Chair) and Renzo L. Ricca (Chair) at the Scuola Normale Superiore.



Opening lecture by Professor H.K. Moffatt.

Chair, keynote lecturers and guests at the conference dinner.

Wine tasting at the San Quintino farmhouse.

Date & Author:

3 October, 2011 (Renzo L. Ricca)