UNIVERSITÀ DELLA CALABRIA
Dipartimento di FISICA

ANNUAL REPORT 2009

ACADEMIC YEAR 2008-2009

Scientific publications in 2009

Table of Contents

GENERAL INFORMATION

RESEARCH ACTIVITY

DEPARTMENTAL ADMINISTRATION

Head of Department:
Pierluigi VELTRI

Executive Board:
Giovanni FALCONE, Luigi SPORTELLI, Giancarlo SUSINNO, Alessandro PAPA, Cesare UMETON, Luigi PAPAGNO, Nicola SCARAMUZZA, Vincenzo FORMOSO

Department Council:
14 Full Professors
19 Associate Professors
20 Senior Researchers
2 Representatives of PhD students
9 Representatives of the Technical and Administrative Staff

Administative Secretary:
Giocondo PERRI

RESEARCH PERMANENT STAFF

Full Professors

1. Riccardo BARBERI	*FIS/07*
2. Roberto BARTOLINO	*FIS/07*
3. Lev BLINOV	*FIS/03*
4. Vincenzo CARBONE	*FIS/07*
5. Elio COLAVITA	*FIS/07*
6. Giovanni FALCONE	*FIS/01*
7. Roberto FIORE	*FIS/02*
8. Ignazio GUERRA	*GEO/10*
9. Antonino OLIVA	*FIS/01*
10. Luigi PAPAGNO	*FIS/01*
11. Luigi SPORTELLI	*FIS/07*
12. Giancarlo SUSINNO	*FIS/01*
13. Cesare UMETON	*FIS/01*
14. Pierluigi VELTRI	*FIS/03*

Associate Professors

1. Raffaele AGOSTINO	*FIS/01*
2. Rosina BARTUCCI	*FIS/07*
3. Assunta BONANNO	*FIS/01*
4. Lorenzo CAPUTI	*FIS/01*
5. Enzo CAZZANELLI	*FIS/03*
6. Gabriella CIPPARRONE	*FIS/03*
7. Gennaro CHIARELLO	*FIS/07*
8. Giovanni CROSETTI	*FIS/01*
9. Laura LA ROTONDA	*FIS/01*
10. Francesco MALARA	*FIS/01*
11. Alessandro PAPA	*FIS/02*
12. Francesco PIPERNO	*FIS/03*
13. Nicola SCARAMUZZA	*FIS/07*
14. Marco SCHIOPPA	*FIS/01*
15. Enrico TASSI	*FIS/01*
16. Carlo VERSACE	*FIS/01*
17. Galileo VIOLINI	*FIS/02*
18. Fang XU	*FIS/01*
19.Gaetano ZIMBARDO	*FIS/06*

Senior Researchers

1. Michele CAMARCA	*FIS/01*
2. Marcella CAPUA	*FIS/01*
3. Roberto CAPUTO	*FIS/03*
4. Tommaso CARUSO	*FIS/07*
5. Anna CUPOLILLO	*FIS/01*
6. Maria DE SANTO	*FIS/07*
7. Vincenzo FORMOSO	*FIS/01*
8. Domenico GIULIANO	*FIS/02*
9. Antonella GRECO	*FIS/07*
10. Rita GUZZI	*FIS/07*
11. Fabio LEPRETI	*FIS/03*
12. Anna MASTOBERARDINO	*FIS/01*
13. Daniela PACILE'	*FIS/01*
14. Pasquale PAGLIUSI	*FIS/07*
15. Francesco PLASTINA	*FIS/01*
16. Leonardo PRIMAVERA	*FIS/05*
17. Pierfrancesco RICCARDI	*FIS/01*
18. Marco ROSSI	*FIS/02*
19. Antonello SINDONA	*FIS/01*
20. Giuseppe STRANGI	*FIS/07*

Post-Doctoral Research Fellows

1. Cristina ADORISIO
2. Francesco CAPORALE
3. Mario COMMISSO
4. Luciano DE SIO
5. Salvatore FAZIO
6. Samah FERJANI
7. Anna GERVASI (*INGV*)
8. Enrico MACCALLINI
9. Salvatore MARINO
10. Ariosto MATRANGA (*CNR/INFM*)
11. Evelin MEONI
12. Giuseppina NIGRO
13. Marco ONOFRI
14. Barbara ORECCHIO
15. Antonio POLICICCHIO
16. Luigia PEZZI
17. Alfonso POLICICCHIO
18. Clementina PROVENZANO
19. Daniela SALVATORE
20. Peppino SAPIA
21. Sergio SERVIDIO
22. Francesco VALENTINI
23. Antonio VECCHIO

Phd Students in Physics

1. Francesco FRANCICA	*(XXII Cycle*)
2. Raffaele MARINO	*(XXII Cycle)*
3. Valentino PINGITORE	*(XXII Cycle)*
4. Massimo VENTURELLI	*(XXII Cycle)*
5. Georgios KALANTZOPOULOS	*(XXII Cycle)*
6. Giacomo BOZZO	(*XXIII Cicle*)
7. Sandro DONATO	(*XXIII Cicle*)
8. Davide Remo GROSSO	(*XXIII Cicle*)
9. Gabriele INFUSINO	(*XXIII Cicle*)
10. Melissa INFUSINO	(*XXIII Cicle*)
11. Gianfranco MORELLO	(*XXIII Cicle*)
12. Roberta VASTA	(*XXIII Cicle*)

Phd Students in Pedagogical Science

1. Fiorina CAPUTO	(*XXIII Cycle*)
2. Filomena COSCARELLA	(*XXIII Cycle*)
3. Angela Maria ZAVAGLIA	(*XXIII Cycle*)

Phd Students in Science and Tecnology of Mesophases and Molecular Materails

1. Said HOUMADI	*(XXII Cycle)*
2. Salvatore ARLIA	*(XXII Cycle)*
3. Lara SELVAGGI	*(XXII Cycle)*
4. Emanuela BRUNO	*(XXII Cycle)*
5. Francesco CARBONE	(*XXIII Cycle*)
6. Ridha HAMDI	(*XXIII Cycle*)
7. Leticia Jimenez	(*XXIII Cycle*)
8. Francesca TEOCOLI	(*XXIII Cycle*)

Phd Students in Physics and Quantum Technology

1. Gennaro CORTESE	(*XXIV Cycle*)
2. Salvatore LORENZO	(*XXIV Cycle*)
3. Silvio PIERRO	(*XXIV Cycle*)
4. Giacinto CIAPPETTA	(*XXV Cycle*)
5. Vincenzo LAVORINI	(*XXV Cycle*)
6. Beatrice MURDACA	(*XXV Cycle*)
7. Amedeo PERRI	(*XXV Cycle*)
8. Michele PISARRA	(*XXV Cycle*)

Phd School "Science and Thecnique":
Curriculum "Physics of Complex Systems

1. Serena DALENA (*XXIV Cycle*)
2. Antonio Raimondo MARINO (*XXIV Cycle*)
3. Antoniou MYRSINI KYRIAKI (*XXIV Cycle*)
4. Giuseppe NISTICO' (*XXIV Cycle*)
5. Fabio COSENZA (*XXIV Cycle*)
6. Giuseppe PUCCI (*XXIV Cycle*)
7. Silvia SALSONE (*XXIV Cycle*)
8. Vincenzo CAPPARELLI (*XXV Cycle*)
9. Denise PERRONE (*XXV Cycle*)
10. Enrico Maria TROTTA (*XXV Cycle*)
11. Angela FASANELLA (*XXV Cycle*)
12. Raul Josuè HERNANDEZ (*XXV Cycle*)
13. Lucia MARINO (*XXV Cycle*)

PhD THESIS' in 2009
(*XXI Cycle*)

Caterina GALLUCCI, Dipartimento di Chimica,
Studio di sistemi Compositi di Polimeri e Cristalli Liquidi con Orientazione Omeotropica
Supervisore: G. DE FILPO

(*XXII Cycle*)
Rosa SALADINO, Dipartimento di Chimica,
Studio di Film elettrocromici innovativi
Supervisore: G. CHIDICHIMO

Tania SPATARO, Dipartimento di Chimica,
Sintesi e studio di nuovi complessi contenenti Zn(II) e Pd(II) con potenziali proprietà elettro-ottiche
Supervisore: I. AIELLO

Huawei LI, Dipartimento di Chimica
Photoconducting e Photorefractive Azo-Polymers
Supervisore: A.GOLEMME

Lara SELVAGGI
Mechanical properties of biopolymers studied at mesoscopic-scale with advanced optical techniqueS
Supervisore: Roberto BARTOLINO

Emanela BRUNO
Scanning probe microscopy studies and dynamic behaviour of ferroelectric domains in pb $zr_{0.53}$ $ti_{0.47}$ o_3 *thin films*
Supervisore: Nicola SCARAMUZZA

Said HOUMADI
Atomic force microscopy study of the physico-chemical properties of hydrophibin protein films
Supervisore: Michele GIOCONDO
(*tesi in cotutela con Università P&M Curie di Parigi*
Supervisore: E. LACAZ

TECHNICAL AND ADMINISTRATIVE STAFF

Administration

1. Giocondo PERRI (*Administrative Secretary*)
2. Gaspare PECORA (*Vice-Administrative Secretary*)
3. Lidia MAIDA
4. Anna Eduardina PASTORE

Secretary

5. Luigina DE ROSE
6. Luigi PARISE

Teaching Laboratories

7. Mario LOMBARDI

Computer Staff

8. Nicola GUARRACINO (*Person in charge*)
9. Fedele STABILE

Research Laboratories

Molecular Physics and Biophysics

10. Bruno DE NARDO (*Person in charge*)
11. Carmine PRETE

Ion-Matter Interaction and Surface Electronic Spectroscopy

12. Eugenio LI PRETI (*Person in charge*)
13. Vito FABIO

Elementary Particles

14. Francesco SCIOMMARELLA
15. Francesco PELLEGRINO

Geophysics

16.Gerolamo LATORRE

The Physics Department hosts a INFM Section with the following staff:
Sonia VIVONA (*Administrative Official - INFM*)
Antonio BOZZARELLO (*Administrative Collaborator*)

Department phonebook
(for calls from outside the Department, dial first (+39)-0984 -49)

INTERNET: @FIS.UNICAL.IT
HTTP: WWW.FIS.UNICAL.IT
FAX: 4401

AGOSTINO Raffaele	6162
BARBERI Riccardo	6118-6150
BARTOLINO Roberto	6122
BARTUCCI Rosina	6074-6073
BLINOV Lev	6124
BONANNO Assunta	6170-6178
BOZZARELLO Antonio	6008
CAMARCA Michele	6172-6178
CAPUA Marcella	6022
CAPUTI Lorenzo	6154-6173
CARBONE Vincenzo	6131-6033
CARUSO Tommaso	6095
CAZZANELLI Enzo	6114-6142
CHIARELLO Gennaro	6157-6174
CIPPARRONE Gabriella	6115-6148
COLAVITA Elio	6156-6174
CROSETTI Giovanni	6021
CUPOLILLO Anna	6160-6174
DE NARDO Bruno	6111-6106
DE ROSE Luigina	6001
DE SANTO Maria Penelope	6150
FORMOSO Vincenzo	6161
GIULIANO Domenico	6025
GRECO Antonella	6132
GUARRACINO Nicola	6030
GUERRA Ignazio	3166
GUZZI Rita	6077-6073
LA ROTONDA Laura	6014-6102
LAMANNA Ernesto	6020-6103
LATORRE Gerolamo	3664
LI PRETI Eugenio	6179-6165
LOMBARDI Mario	6083
MAIDA Lidia	6006
MALARA Francesco	6135-6033
MASTROBERARDINO Anna	6031
OLIVA Antonino	6167-6178
PAGLIUSI Pasquale	6148
PAPA Alessandro	6015
PAPAGNO Luigi	6158-6174
PARISE Luigi	6002
PECORA Gaspare	6005
PELLEGRINO Francesco	6102-6098
PERRI Giocondo	6004
PIPERNO Franco	6058
PLASTINA Francesco	6046
PRIMAVERA Leonardo	6138
PRETE Carmine	6142
RICCARDI Pierfrancesco	6171-6178
SCARAMUZZA Nicola	6113-6151
ROSSI Marco	6020
SCHIOPPA Marco	6017-6104
SCIOMMARELLA Francesco	6011
SINDONA Antonello	6059
SPORTELLI Luigi	6076-6073
STABILE Fedele	6027
STRANGI Giuseppe	6120
SUSINNO Giancarlo	6016-6104
UMETON Cesare	6117-6152
VELTRI Pierluigi	6136-6033
VERSACE Carlo	6116-6147
VIOLINI Galileo	6024
VIVONA Sonia	6007
XU Fang	6168-6178
ZIMBARDO Gaetano	6134-6033

Network and Computer Service	*6035*
Medical Physics Lab.	*6068*
Astrophysical Plasmas Computer Lab.	*6033*
Ion-Matter Interaction Lab.	*6178*
Electronic Spectroscopy Lab.	*6174*
Biophysics Lab.	*6073*
Molecular Physics Lab.	*6151*
Particle Physics Lab.	*6104*
Mechanical Workshop	*6006*

SEMINARS (2009)

Feb 9, 2009

Luc Ortega *(CNRS-Institut NEEL, Grenoble, Francia)*

Ultra thin films characterization using x-ray labs source

Feb 24, 2009

S. Maniscalco

Non-Markovian Quantum Jumps

Mar 10, 2009

Igor Cherednikov **(***Affiliato INFN Co*senza)

Funzioni di distribuzione partoniche dipendenti dal momento trasverso nello studio dei processi adronici semi-inclusivi

Mar 12 2009

Sergey Savin (*Space Research Institute, Mosca*)

Superdiffusion versus percolation at high latitude magnetopause

Mar 31, 2009

A. Andrianov (*Univ. Barcellona***)**

*Rottura della parita` in QCD sotto condizioni estr*eme

Apr 8, 2009

Sergio Servidio

Magnetic Reconnection in Two-Dimensional Magnetohydrodynamic Turbulence

Apr 20, 2009

Milena Toselli

Sicurezza nei Laboratori Scientifici:aspetti generali e specifici-Testo Unico DLgs 81/2008

Apr 21, 2009

Milena Toselli

Aspetti Tecnici: sicurezza, attrezzature, laser, sicurezza elettrica, sicurezza chimica, radiazioni ionizzanti e rischio biologico

Apr 22, 2009

Milena Toselli

Gestione delle emergenze, test ed esercitazione

May 7, 2009

Cinzia Da Via

3D silicon detectors for high energy physics and medical applications

May 12, 2009

Salvatore Stramondo

Interferometria SAR nello studio dei terremoti: primi risultati in Abbruzzo

May 19, 2009

Richard Wigmans *(Texas Tech University)*

Dual Readout Calorimetry

May 20, 2009

Martini Matteo

The kaon physics with KLOE2 experiment at Dafne accelerator

May 20, 2009

De Santis Antonio (*INFN/Roma1*)

Highlights on hadron physics with KLOE2 experiment

May 21, 2009

Enzo BARONE (*Scuola Normale Superiore, Pisa*)

DREAMS: Distributed Research Environment for the Advancement of Molecular Sciences

May 21, 2009

Francesco Califano (*Dipartimento di Fisica, Università di Pisa*)

Il sistema di equazioni Maxwell-Vlasov ibrido: una tematica di confine nel settore HPC

May 22, 2009

Piero Palizzari (*Ylichron SRL, c/o ENEA C.R.)*

HARWEST Compiling Environment (HCE): programmare sistemi FPGA mediante il linguaggio ANSI-C

May 22, 2009

Nico Sanna (*CASPUR*)

New trends of HPC in Italy…

Jun 9, 2009

Pasquale Sodan *(Università di Perugia)*
Teorie di Campo di Modelli di Spin (I)

Jun 10, 2009

Pasquale Sodano *(Università di Perugia)*

Teorie di Campo di Modelli di Spin (II)

Jun 24, 2009

Sebastiano D'Amico (*Dept of Earth Sciences – St Louis University*)

Determinazione del tensore momento sismico per terremoti di bassa energia

Jun 24, 2009
Guido Martinelli (*Università di Roma "La Sapienza" ed INFN-Roma*)
UT analysis and the implications of a large phase in Bs mixing

Jun 24, 2009
Sebastiano D'Amico (*Dept of Earth Sciences – St Louis University*)
Il meccanismo al fuoco del terremoto abruzzese del 6 aprile

Jul 24, 2009
Sergio Servidio
Turbulent relaxation of an electron plasma

Oct 5, 2009
V.A. Belyakov (*Landau Institute for Theoretical Physics, Mosca*)
Low Threshold Lasing at Edge and Defect Optical Models in Chiral Photonic Liquid Crystals

Oct 8, 2009
Emilio Martines (*Consorzio RFX, Associazione Euratom-ENEA sulla Fusione, Padova*)
Stati a singola elicita' in plasmi di intersse fusionistico confinati magneticamente in configurazione RFP

Oct 28. 2009
William H. Matthaeus (*Bartol Research Institute, University of Delaware, USA*)
1° seminario: Short review of hydrodynamic turbulence theory - 2° seminario:MHD models and turbulence

Oct 29, 2009
William H. Matthaeus (*Bartol Research Institute, University of Delaware, USA*)
1° seminario: Self-organization in turbulence - 2° seminario: Solar wind as a turbulent medium

Oct 30, 2009
William H. Matthaeus (*Bartol Research Institute, University of Delaware, USA*)
Energetic particle scattering and acceleration in turbulence

Nov 12, 2009
Metamateriali: nuove frontiere in ottica e nelle nanoscienze

Dec 7, 2009
Antonio Sasso *(Dipartimento di Scienze Fisiche Universita' di Napoli "Federico II")*
Raman Tweezers

Dec 10, 2009
Francesco Scarpelli *(Department of Molecular Physics, Leiden University, The Netherlands)*
Structure determination and distance measurements in biological systems (seminario della scuola di dottorato "B. Telesio")

LAUREA THESIS' IN 2009

May 5 *(a.y. 2007-08)*
Gianpaolo MALAVENDA
Studio dell'oscillatore anarmonico con i diagrammi di Feynman.
Relatore***:*** Alessandro PAPA

Dec 9 *(a.y. 2008/09)*
Giacinto CIAPPETTA
Modelli teorici per la diffusi Compton profondamente Anelastica.
Relatore: Roberto FIORE

1st LEVEL DEGREE THESIS' IN 2009

May 7 (*a.y. 2008/09*)
Stefania EVOLI
Sottostati conformazionali in proteine alla temperatura di "glass transition".
Relatore: Rita Guzzi

July 21 (*a.y. 2008/09*)
Giovanni Francesco CELIBERTO (*a.y. 2008/09*)
Dipendenza dalla temperatura nella scintillazione di cristalli di PbWO4
Relatore: Alessandro PAPA

Sept 30 (*a.y. 2008/09*)
Claudia ROSSI (*a.y. 2008/2009*)
Turbolenza nella cromosfera solare
Relatore: Vincenzo *CARBONE*

Gilda STELLATO (*a.y. 2007-08*)
Controllo qualitativo di dati GPS
Relatore: Ignazio GUERRA

Sept 30 (*a.y. 2007-08*)
Gaetano DE VITA (*a.y. 2007-08*)
Analisi dati da satelliti artificiali
Relatore: Gaetano ZIMBARDO

Cristina LABATE (*a.y. 2008/09*)
Caratterizzazione elettrica di film sottili con tecniche di microscopia a scansione.
Relatore: Maria Penelope DE SANTO

Marco CAPUTO (*a.y. 2008/09*)
Preparazione e caratterizzazione di cluster Au su MgO/Ag(100).
Relatore: Gennaro CHIARELLO

Ilaria BONETTI (*a.y. 2008/09*)
Dosimetria a basse dosi con materiali innovativi
Relatore: Anna SANTANIELLO

Antonio DE LIGUORO (*a.y. 2008/09*)
Equazione di Dirac nel campo di un solitone e stati elettronici a gap nulla.
Relatore: Domenico GIULIANO

Alessandro CRISTALLO (*a.y. 2008/09*)
Dinamica di eccitazioni di spin a statistica frazionaria in antiferromagnete in una dimensione.
Relatore: Domenico GIULIANO

Victor LAZZAROLI (*a.y. 2008/09*)
Misura della relazione spazio-temporale delle camere MTD di ATLAS mediante test su fascio di particelle con tracciatore esterno di altissima precisione.
Relatore: Marco SCHIOPPA

Dec 16
Annamaria GIORNO (*a.y. 2008/09*)
Analisi POD di dati di risonanza magnetica cardiaca.
Relatore: Anna SANTANIELLO

Elisa NAPOLI (*a.y. 2008/09*)
Misura della risoluzione spaziale in campo magnetico del rivelatore G.E.M. per l'esperimento KLOE-2 all'acceleratore e+ e- DAGNE dei LNF.
Relatore: Marco SCHIOPPA

Andrea GNISCI (*a.y. 2008/09*)
Studio delle prorpiet‡ elettroniche e di geometria locale di superfici di ossido di titanio mediante tecniche di assorbimento di raggi X o elettroni di alta energia.
Relatore: Raffaele Giuseppe AGOSTINO

Antonio ALECCE (*a.y. 2008/09*)
Entanglement nell'interazione radiazione-materia in due cavit‡ ideali non comunicanti perfettamente risonanti.
Relatore: Francesco PLASTINA

Amedeo IPPOLITO (*a.y. 2008/09*)
Analisi della turbolenza nell'esperimento di plasma RFX.
Relatore: Fabio LEPRETI

2nd LEVEL DEGREE THESIS' IN 2009

July 22
Vincenzo LAVORINI (*a.y. 2008/09*)
Study of the production of the top quark with the ATLAS detector at the LHC.
Relatore: Enrico TASSI

Vincenzo CAPPARELLI (*a.y. 2008/09*)
Cambiamenti climatici e stagionalit‡: anomalie e variazioni di fase del ciclo annuale delle temperature.
Relatore: Vincenzo CARBONE

Denise PERRONE (*a.y. 2008/09*)
A shell model for turbulent dynamos.
Relatore: Pierluigi VELTRI

Beatrice MURDACA (*a.y. 2008/09*)
Produzione di jet di Mueller-Navelet nelle collisioni adrone-adrone.
Relatore: Alessandro PAPA

Nicolino, Biagio LO GULLO (*a.y. 2008/09*)
Studio di sistemi di spin vicino al punto di fattorizzazione.
Relatore: Francesco PLASTINA

Sept 30
Michele PISARRA (*a.y. 2008/09*)
Studio di emissione di elettroni nell'interazione di ioni con superfici metalliche.
Relatore: Pierfrancesco RICCARDI

Enrico Maria TROTTA
Diffusione di particelle energetiche di origine solare.
Relatore: Gaetano ZIMBARDO

Amedeo PERRI
Studio della sezione d'urto per la produzione di due Jet di Mueller-Navelet nella collissione protone-protone.
Relatore: Alessandro PAPA

Antonio IAZZOLINO
Simulazioni cinetiche per lo studio dell'interazione risonante con onde ION-CYCLOTRON in regime lineare e non lineare.
Relatore: Francesco VALENTINI

PhD THESIS' in 2009

(*22° Cycle*)
Francesco FRANCICA
Entanglement dynamics in a cavity and its protection by the quantum zeno effect
Supervisore: Francesco PLASTINA

Georgious KALANTZOPOULOS
Hydrogen Physisorption Processes on Porous Solids
Supervisore: Raffaele Giuseppe AGOSTINO, Enrico MACCALINI

Raffaele MARINO
Scaling laws in solar wind turbulence
Supervisore: Vincenzo CARBONE, Alain NOULLEZ, Luca SORRISO-VALVO

Valentino PINGITORE
Implementation of CL apparatus coupled with a S.E.M. : results and applications
Supervisore: Antonino OLIVA

1. ASTROPHYSICS

Professors and Researchers

Pierluigi Veltri
Vincenzo Carbone
Francesco Malara
Gaetano Zimbardo
Leonardo Primavera
Antonella Greco
Fabio Lepreti
Luca Sorriso-Valvo *(LICRYL, INFM/CNR Cosenza)*

Postdoc fellows

Antonio Vecchio
Francesco Valentini
Marco Onofri
Sergio Servidio
Giuseppina Nigro

PhD students

Raffaele Marino
Sandro Donato
Giuseppe Nisticò
Serena Dalena

Collaborators

S. Perri *(International Space Science Institute, Bern, Switzerland)*
A. Mangeney *(Observatoire de Paris-Meudon, Paris, France)*
W. H. Matthaeus *(Bartol Research Institute, Newark, Delaware, USA)*
T. M. O'Neil *(Physics Dept., University of California at San Diego, California, USA)*
D. H. E. Dubin *(Physics Dept., University of California at San Diego, California, USA)*
F. Anderegg *(Physics Dept., University of California at San Diego, California, USA)*
C. F. Driscoll *(Physics Dept., University of California at San Diego, California, USA)*
C. Cavazzoni *(CINECA, Bologna, Italy)*
V. G. Kossobokov *(Russian Academy of Sciences, Moscow, Russia)*
A. Noullez *(Observatoire de la Cote d'Azur, Nice, France)*
E. Yordanova *(International Space Sciece Institute, Bern, Switzerland)*
R. Bruno *(IFSI - CNR, Frascati, Italy)*
A. Mura *(IFSI - CNR, Frascati, Italy)*
A. Milillo *(IFSI - CNR, Frascati, Italy)*
S, Orsini *(IFSI - CNR, Frascati, Italy)*
T. Zhang *(Space Research Institute, Austrian Academy of Sciences)*
H. Biernat *(Space Research Institute, Austrian Academy of Sciences)*
H. Rucker *(Space Research Institute, Austrian Academy of Sciences)*
W. Baumjohann *(Space Research Institute, Austrian Academy of Sciences)*
D. Jankovikova *(IAP, Czech Republic)*
P. Kovacs *(ELGI, Budapest Hungary)*
R. D'Amicis *(IFSI - CNR, Frascati, Italy)*
B. Bavassano *(IFSI - CNR, Frascati, Italy)*
M. B. Cattaneo *(IFSI - CNR, Frascati, Italy)*
M. André *(Swedish Institute of Space Physics, Uppsala, Sweden)*
M. Bourgoin *(LEGI, Université Joseph Fourier, Grenoble, France)*
P. Odier *(LEGI, Université Joseph Fourier, Grenoble, France)*
N. Plihon *(LEGI, Université Joseph Fourier, Grenoble, France)*
R. Volk *(LEGI, Université Joseph Fourier, Grenoble, France)*
I. Guerra *(Dipartimento di Fisica, Università della Calabria, Rende, Italy)*
D. Meduri *(Dipartimento di Fisica, Università della Calabria, Rende, Italy)*
G. Cauzzi *(Osservatorio Astrofisico di Arcetri, Florence, Italy)*
K. Reardon *(Osservatorio Astrofisico di Arcetri, Florence, Italy)*
P. Chuychai *(Bartol Research Institute, Newark, Delaware, USA)*
M. Shay *(Bartol Research Institute, Newark, Delaware, USA)*
M. Wan *(Bartol Research Institute, Newark, Delaware, USA)*

D. J. Rodgers *(Bartol Research Institute, Newark, Delaware, USA)*
T. Mitchell *(University of Delaware, Newark, USA)*
T. Aziz *(Bartol Research Institute, Newark, Delaware, USA)*
D. C. Montgomery *(Department of Physics and Astronomy, Dartmouth College, USA)*
S. Oughton *(Department of Mathematics, University of Waikato, New Zealand)*
P. Cassak *(Department of Physics, West Virginia University,USA)*
P. Dmitruk *(Departemento de Fisica, Universitad de Buenos Aires, Argentina)*
J. A. Klimchuk *(NASA, GSFC, USA)*
R. B. Dahlburg *(Naval Research Laboratory, Washington DC, USA)*
A. Taktakishvili *(Abastumani Observatory, Tbilisi, Georgia, and Goddard Space Flight Center, NASA, USA)*
Z. Voros *(Institute for Astro- and Particles Physics, University of Innsbruck, Innsbruck, Austria)*
L. Zelenyi *(Space Research Institute, Moscow, Russia)*
S. Patsourakos *(Department of Physics, University of Ioannina, Greece)*
A. Artemyev *(Space Research Institute, RAS, Moskow, Russia)*
H. Malova *(Space Research Institute, RAS, Moskow, Russia)*
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Introduction

The research in Astrophysics in the Physics Department of University of Calabria is mainly devoted to study plasma physics. Most of interplanetary matter and of the solar atmosphere is actually formed by plasma. For that reason, most of data obtained in space missions, or by solar observatories, can be interpreted within the framework of plasma physics. Such data have allowed for the construction of models describing astrophysical phenomena, and they have represented a powerful tool of investigation which has often given new perspectives for the comprehension of phenomena in fundamental physics. This has allowed to use the space as a huge laboratory where measurements not accessible in a terrestrial laboratory can be performed. On the other hand, using analogue techniques both on space and on laboratory measures allows for a comparison of the basic physical phenomena that take place on completely different scales, and for a comprehension of such phenomena which are relevant both in the domain of controlled thermonuclear fusion and in the perspective of industrial applications.

The group of Astrophysical Plasmas of Calabria University has been involved in such kind of problems, in collaboration with other groups of Italian universities (Pisa, Rome “La Sapienza”, Milano) and with Italian Institutions (IFSI - CNR of Frascati, Osservatorio Astrofisico di Arcetri, Consorzio RFX of Padova; CINECA, Bologna, Italy, INFN Milano) and foreign Institutions (Observatoire de Paris-Meudon, Paris (France); Observatoire de la Cote d'Azur, Nice (France); LEGI, Université Joseph Fourier, Grenoble (France); Laboratoire Physique del Plasmas, CNRS, Sain-Maur-des-Fossé France); Department of Physics, University of Ioannina (Greece); Institute for Astro- and Particles

Physics, University of Innsbruck (Austria); Space Research Institute, Austrian Academy of Sciences (Austria); Goettingen University (Germany); IAP (Czech Republic); ELGI, Budapest (Hungary); Swedish Institute of Space Physics, Uppsala (Sweden); International Space Science Institute, Bern (Switzerland); Russian Academy of Sciences, Moscow (Russia); Space Research Institute, Moscow (Russia); Bartol Research Institute, Newark, Delaware (USA); University of Delaware, Newark (USA); Department of Physics and Astronomy, Dartmouth College (USA); Physics Dept., University of California at San Diego, California (USA); Department of Physics, West Virginia University (USA); NASA, GSFC (USA) ; Naval Research Laboratory, Washington DC (USA); Goddard Space Flight Center, NASA (USA); Abastumani Observatory, Tbilisi (Georgia); Nodia Geophysics Institute, Tbilisi University (Georgia); Departemento de Fisica, Universitad de Buenos Aires (Argentina); Department of Mathematics, University of Waikato (New Zealand)). The specific research themes under study during the year 2009 are described in the following.

1.1 MAGNETOHYDRODYNAMIC TURBULENCE AND KINETIC EFFECTS IN THE INTERPLANETARY SPACE

Third-order law for Magnetohydrodynamic with constant velocity shear

The Yaglom-law for magnetohydrodynamic (MHD) turbulence relates the statistics of the third-order mixed momenta of velocity and magnetic field fluctuations to the characteristic scale of fluctuations through the transfer rate of turbulent energy to small scales. This theory for third-order structure functions, valid only in homogeneous and incompressible systems, has been extended to the case in which a constant velocity shear is present. A generalization is found of the usual relation between third-order structure functions and the dissipation rate in steady inertial range turbulence, in which the shear plays a crucial role. In particular, the presence of shear leads to a third-order law which is not simply proportional to the relative separation. Using direct numerical simulations of two-dimensional (2D) MHD turbulence with shear, this new generalization of the theory has been confirmed. The presence of the shear effect broadens the circumstances in which the law can be applied. This extension of the Yaglom-law may have possible implications for laboratory and space plasmas.

Local processed in MHD turbulence and non-Gaussian statistics

Two central features of magnetohydrodynamic (MHD) turbulence are generally studied independently: the production of intermittency and the appearance of distinctive states associated with turbulent relaxation. It is, for example, well known that the random phase approximation fails as a turbulence description in that it cannot produce non-Gaussian statistics, such as high kurtosis of vorticity and current, multifractal scaling of moments, and other signatures of intermittency. On the other hand, MHD relaxation theory has led to notable successes associated with Taylor relaxation, selective decay, global dynamic alignment, and helical dynamo action.
Direct numerical simulations show that undriven MHD turbulence spontaneously generates coherent spatial correlations of several types, associated with local Beltrami fields, directional alignment of velocity and magnetic fields, and anti-alignment of magnetic and fluid acceleration components. These correlations suppress nonlinearity to levels lower than what is obtained from Gaussian fields, and occur in spatial patches. We suggest that this rapid relaxation leads to non-Gaussian statistics and spatial intermittency. To further confirm this scenario, we have performed spectral method simulations of ideal MHD, investigating the production of coherent small scale structures. The near-identical growth (in the initial stage) of non-Gaussianity in ideal and non-ideal cases suggests that generation of coherent structures and breaking of self-similarity are essentially ideal processes. This has important implications for understanding the origin of intermittency in turbulence.

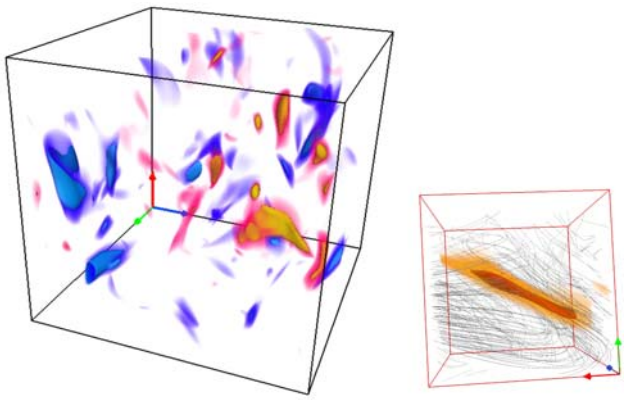

Fig. 1.1*: An example of magnetic reconnection in 3D turbulence. On the left: the current density structure in a highly turbulent magnetic field is represented by isosurfaces and color clouds. On the right: a blow-up of the same magnetic field is represented with locally reconnecting magnetic lines.*

Magnetic reconnection in turbulence

Magnetic reconnection is a nonlinear process that occurs in many space, astrophysical, and laboratory systems. The underlying common feature for these systems is the presence of an inhomogeneous magnetic field that changes rapidly across a very narrow region. Generally, a strong peak in the electric current density is present. Reconnection implies the presence of a magnetic X-type neutral point in two-dimensions (2D), and more generally a change in magnetic topology resulting in the conversion of magnetic into kinetic energy. Since it might occur in any region separating topologically distinct magnetic flux structures, reconnection might be expected to be of importance in more general circumstances, including magnetohydrodynamic (MHD) turbulence (Fig. 1.1). Very high resolution numerical simulations of 2D MHD turbulence reveal the presence of a large number of X-type neutral points where magnetic reconnection occurs. In this scenario, reconnection is spontaneous, but locally driven by the fields and boundary conditions provided by turbulence itself. Because of the complex magnetic topology, turbulence leads to different kinds of reconnecting patches. In contrast with laminar reconnection models that provide a single predicted reconnection rate for the system, turbulent resistive MHD gives rise to a broad range of reconnection rates that depend on local turbulence parameters. Many potential reconnection sites are present, but only a few are selected by the turbulence, at a given time, to display robust reconnection electric fields. In this way, the present problem differs greatly from studies of reconnection that assume that it occurs in isolation. In turbulence the associated reconnection rates are distributed over a wide range of values and scales with the geometry of the diffusion region. Locally, these events can be described through a variant of the Sweet-Parker model, in which the parameters are externally controlled by turbulence. This new perspective on reconnection is relevant in space and astrophysical contexts, where plasma is generally in a fully turbulent regime.

Intermittent structures and magnetic discontinuities in MHD turbulence and solar wind

We re-examine the statistics of rapid spatial variations of the magnetic field in simulations of Hall magnetohydrodynamic (HMHD) turbulence, using analysis of intermittency properties of the turbulence, and also using methods often employed to identify discontinuities in the solar wind (as in the earlier work of Tsurutani & Smith 1979). The hypothesis is that the statistics of intermittent events might be related to the statistics of classical MHD discontinuities. Indeed, those methods give similar distributions of events, often identifying the same structures. This suggests that observed discontinuities might not be static solutions to the MHD equations, but instead may be related to the intermittent structures that appear spontaneously in MHD turbulence. Then, we further examine the link between intermittency and MHD discontinuities, directly comparing statistical analysis from solar wind data and 3D and 2D simulations of MHD turbulence. The comparison between ACE solar wind data and simulations of magnetohydrodynamic turbulence shows a good agreement in the Waiting-Time analysis of magnetic field discontinuities. This result adds to evidence that solar wind magnetic structures may emerge fast and locally from nonlinear dynamics that can be properly described in the framework of MHD theory.
Different techniques for the identification of reconnection sites in fully developed turbulence are studied. Using high Reynolds number simulations of two-dimensional magnetohydrodynamic (2D MHD) turbulence, a possible link between tangential discontinuities and magnetic reconnection is under investigation. Previous studies on discontinuities and theories of reconnection in turbulence are combined in order to identify possible reconnection events along a one-dimensional path through the 2D field. The goal is to develop numerical algorithms that may be useful for solar wind applications.

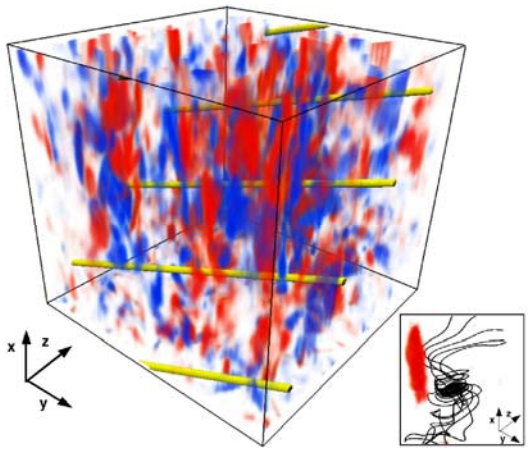

Fig. 1.2*: 3D view of current density J_x in a portion of the simulation box (red, J_x >0; blue, J_x <0). Yellow lines are sample trajectories that mimic the spacecraft crossing of the solar wind. The inset shows an example of helical magnetic field lines (black) suggesting a flux tube bounded by a current sheet (red).*

Hydrodynamic Relaxation of an Electron Plasma

Electron traps allow for the experimental study of two-dimensional (2D) turbulence, when the leading order description of the plasma is that of a guiding center fluid. Then, the governing dynamical equations correspond to 2D hydrodynamics, up to constants of proportionality. This is perhaps the simplest case of self-organizing turbulence, and is therefore a paradigm for Taylor relaxation, selective decay and other fluid and plasma relaxation processes, with diverse implications ranging from superfluids, to astrophysics and planetary atmospheres. Two-dimensional relaxation has a well demonstrated sensitivity to the initial data and electron trap dynamics are no exception. The dynamical relaxation of a pure electron plasma in a Malmberg-Penning trap is studied, comparing experiments, numerical simulations and statistical theories of weakly dissipative 2D turbulence. Simulations confirm that the dynamics are approximated well by a 2D hydrodynamic model. Statistical analysis favours a theoretical picture of relaxation to a near-maximum entropy state with constrained energy, circulation, and angular momentum. Our analysis suggests that relaxation is better described by a maximum entropy principle rather than by a minimum enstrophy principle. The maximum entropy perspective requires that no ad hoc allowances need to be made for the appearance of negative electron densities. The disparity between the two predictions grows as does the intensity of turbulence involved in the relaxation process. This provides evidence that 2D electron fluid relaxation in a turbulent regime is governed by principles of maximum entropy, and suggests a larger influence of statistical mechanical considerations when the system is free to explore its phase space to a greater extent, as it is in the presence of turbulence.

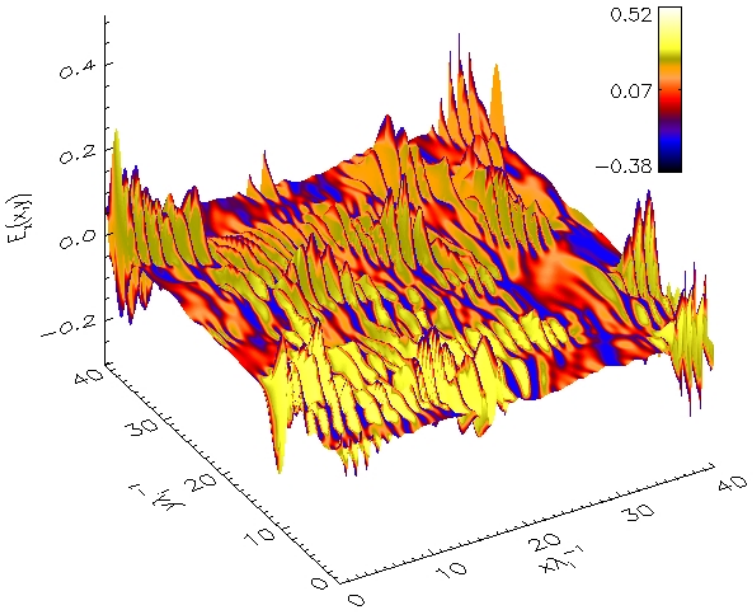

Fig. 1.3*: The electrostatic wavepackets in parallel propagation with respect to the ambient magnetic field, generated through kinetic effects in the short-scale termination of turbulence in the solar wind.*

Short-scale termination of solar wind turbulence

In interplanetary plasmas, due to the absence of collisional viscosity, fundamental questions about how energy is transfered from large to small scales and how it is eventually dissipated are still open. Since astrophysical plasmas are known to be highly turbulent, the understanding of the role of turbulence in such collisionless systems would be of key relevance for the explanation of the energy transport and heating problem in space. The fast technological development of supercomputers gives nowadays the possibility of using kinetic Eulerian Vlasov codes that solve the Vlasov-Maxwell equations in multi-dimensional phase space. The use of these "zero-noise" codes is crucial in the analysis of the development of turbulent spectra at typical kinetic scales, where the energy level of the fluctuations is typically very low. To study the system dynamics at frequencies of the order of the ion cyclotron frequency, we built up a hybrid-

Vlasov model (Fig. 1.3), in collaboration with Prof. A. Mangeney (Observatory of Paris-Meudon) and Prof. F. Califano (Università di Pisa). Within this model, the ion dynamics is described through the Vlasov equation and the electrons are treated as a fluid. A generalized Ohm equation, that retains Hall effect and electron inertia terms, is considered. Faraday equation, Ampere equation (the displacement current is neglected) and an equation of state for the electron pressure close the system. Quasi-neutrality is assumed. The above equations are solved through a numerical hybrid-Vlasov code in a multi-dimensional phase space (typically 1-D or 2-D in physical space and 3-D in velocity space), discretized on a uniform Cartesian grid. Our numerical analysis showed that the electrostatic turbulence in space plasmas with plasma beta of the order of unity (typical value for the solar wind) consists of longitudinal waves with dispersion relations of the acoustic form and it is associated with the generation of ion-beam distributions. Beside the ion-acoustic branch, which is in agreement with solar wind data from Helios 1 and 2 spacecraft, the kappa-omega spectrum of the numerical signals indicates the presence of a new branch of kinetic waves propagating at velocity close to the ion thermal speed. These waves are driven by kinetic effects of particle trapping and are stable against Landau damping due to the formation of trapping plateaus in the ion velocity distributions. We found that these novel kinetic fluctuations are nonlinear Bernstein-Green-Kruskal-like (BGK) solutions of the hybrid Vlasov-Maxwell equations, driven by particle trapping phenomena. In fact, taking into account particle trapping allows for the existence of fluctuations with phase speed in the bulk of the ion velocity distribution, which represent a privileged way for electrostatic turbulence to develop towards short scales.

A massive parallelizzation process on the numerical algorithm through which the hybrid – Vlasov equations are solved, performed in collaboration with Dr. Carlo Cavazzoni (CINECA), allowed for the first time simulations of turbulence at short wavelengths in the solar wind in a 2D-3V phase space(2D in physical space and 3D in velocity space) with significant numerical resolution. The results of these simulations open a new scenario in the study of kinetic effects in the dynamics of space plasmas. In fact, through our numerical analysis we give evidence that in presence of a background magnetic field the longitudinal direction can be a preferential channel to transfer the energy injected at large wavelengths towards short kinetic scales. We found that this channel consists of electrostatic fluctuations driven by particle trapping effect. The analysis of the numerical signals showed that this dynamics favors the generation of longitudinal anisotropy in the energy spectra. It is worth noting that previous MHD or PIC simulations in regime of large wavelengths predicted the generation of perpendicular anisotropy, then our results point out that the inclusion of kinetic effects is crucial in the description of the solar wind dynamics at short scales.

Kinetic acoustic-like fluctuations driven by particle trapping effects

The novel kinetic electrostatic fluctuations recovered in the hybrid-Vlasov simulations of turbulence in solar wind plasmas turn out to be analogous (at low frequency) to the so-called electron acoustic waves (EAWs), which are acoustic-like fluctuations at phase speed close to the electron thermal speed. An EAW is a nonlinear wave with a carefully tailored trapped particle velocity distribution. Within linear theory an EAW would be heavily Landau damped, since the wave phase velocity is comparable to the thermal speed. However, the EAW is a Bernstein-Greene-Kruskal (BGK) nonlinear mode with electrons trapped in the wave troughs. Because of the trapped electrons, the velocity distribution is effectively flattened at the wave phase speed, and this turns off Landau damping. We proved the existence of these kinetic oscillations, predicted within kinetic theory, both numerically through PIC and Vlasov simulations and experimentally in a pure ion plasma apparatus, in collaboration with the nonneutral plasma laboratory at University of California at San Diego, lead by Prof. T. O'Neil. These kind of machines (Penning-Malmberg traps) are extremely useful for the study of fundamental physics in the kinetic regime, since the confining time of the nonneutral plasmas is of the order of several days. For example, it is possible to investigate the energy exchange between waves and particles in Landau damping phenomena both in linear and nonlinear regimes or the nature of the instabilities driven by nonthermal distributions of particle velocities as well as plasma heating processes. This kind of analysis is relevant in the interpretation of physical phenomena also observed in space plasmas.

1.2 OBSERVATIONS AND TURBULENCE MODELS IN THE SOLAR ATMOSPHERE

Nonlinear development of current sheet instability for a solar coronal loop

We investigated the dynamics of the coronal plasma in order to understand the physical mechanism responsible for nanoflares. Studying the dynamical behaviour of a current sheet in a plasma system with line-tied boundary conditions, we can relate the explosive plasma instability, which takes place in this framework, to the impulsive energy release thought to take place in a solar coronal loop. Within this interpretation, we want to investigate a basic situation in which the instability develops in a specific magnetic topology driven by a shearing velocity at the boundaries of the simulation box (top and bottom). Imposing a velocity shear at boundary, we expect the formation of current sheets which undergo a fragmentation after the saturation of the tearing modes and the secondary instability. In this case we expect also the formation of energy spectra (kinetic and magnetic energy spectra) with a power-law range with slope around two. The line-tied boundary condition however strongly restricts the plasma dynamics. We want to study closely this situation in order to understand how the energy which heats the corona is derived from stresses that

have built up in the magnetic field. We solve the cold plasma MHD equations with a background homogeneous magnetic field neglecting loop curvature by using a new parallelized viscoresistive three-dimensional code. The code employs a Fourier collocation-finite difference spatial discretization, and uses a third-order Runge-Kutta temporal discretization.

Dynamics of the solar chromosphere

The exact nature of the quiet solar chromosphere and especially its temporal variation, are still subjects of intense debate. One of the contentious issues is the possible role of the magnetic field in structuring the quieter solar regions. This is the motivation that has led our research group, in collaboration with the Osservatorio Astrofisico di Arcetri, to concentrate on multiwavelength observations and interpretation of small scale phenomena, both in the quiet and active Sun. In particular, we characterize the dynamics of the quiet inter-network chromosphere by studying the occurrence of acoustic shocks and their relation with the concomitant photospheric structure and dynamics, including small scale magnetic structures. For this scope we use the Interferometric Bidimensional Spectrometer (IBIS) which has been built at Arcetri and is presently installed at the Dunn Solar Telescope of the US National Solar Observatory. By analyzing a comprehensive data set that includes high-resolution chromospheric (Ca II 854.2 nm) and photospheric (Fe I 709.0 nm) spectra we have identified the spatio-temporal occurrence of the acoustic shocks and compared it with the photospheric dynamics by means of both Fourier and wavelet analysis and study the influence of magnetic structures on the phenomenon. Mid-chromospheric shocks occur within the general chromospheric dynamics pattern of acoustic waves propagating from the photosphere. In particular, they appear as a response to underlying powerful photospheric motions at periodicities nearing the acoustic cut-off, consistent with 1-D hydrodynamical modeling. However, their spatial distribution is highly dependent on the local magnetic topology. We find that large portions of the fields of view undergo very few shocks, since they are "shadowed" by the horizontal component of the magnetic field. The latter is betrayed by the presence of chromospheric fibrils, namely slanted structures with distinct dynamical properties.

Our results indicate that the magnetic field might play a larger role in structuring the quiet solar chromosphere than normally assumed. The presence of fibrils highlights a clear disconnection between the photospheric dynamics and the response of the geometrically overlaying chromosphere. As these results hold for a mid-chromospheric indicator such as the Ca II 854.2 line, it is expected that diagnostics formed in higher layers, such as UV lines and continua, will be affected to a greater extent by the presence of magnetic fields, even in quiet regions. This is relevant for the chromospheric models that make use of such diagnostics.

Turbulence in the solar chromosphere

Convective and oscillatory motions occurring in the Sun interior continuously inject energy in the solar atmosphere and perturb its magnetic structure, giving rise to several non-linear dynamical processes and turbulence phenomena. The behaviour of the outer layers of the solar atmosphere (chromosphere and corona) at small spatial and time scales still presents many open questions and is an ongoing subject of study. In particular, the nature of the solar chromosphere and the source of its heating remains one of the main open problems of solar physics. In this framework, the role played by turbulence has not yet been investigated in sufficient detail. We have studied the acoustic properties of the solar chromosphere in the high-frequency regime using a time sequence of velocity measurements in the chromospheric Ca ii 854.2 nm line taken with the Interferometric Bidimensional Spectrometer (IBIS). By using the Yaglom law for third order moments of velocity increments we have estimated the energy dissipation rate of acoustic turbulence in regions of the solar chromosphere with different magnetic properties. The results of this analysis suggests that the turbulent dissipation could give a significant contribution to the heating of the chromosphere.

Energy balance and cascade in MHD turbulence in the solar corona.

The dynamics of fluctuations in a closed coronal structure is regulated by two phenomena: the resonance excited by motions at the loop basis, that stores energy within the loop; nonlinear couplings, that move energy towards smaller scales. We extended a previous work that had been carried out considering a uniform background to the case of a nonuniform density, in order to include possible effects due to the longitudinal stratification in a loop. In fact, density inhomogeneities affect the properties of resonant eigenmodes (frequencies and spatial profiles) which, in turn, could modify the nonlinear couplings among eigenmodes thus affecting the energy balance. Preliminar results shows that the basic aspects of phenomenology, namely: the input energy flux, the nonlinear flux and the level of velocity fluctuations are non substantially modified by the presence of a longitudinal density inhomogeneity.

Coronal heavy ion reflection and heating by quasi-perpendicular collisionless shocks.

We propose a new model for explaining the observations of preferential heating of heavy ions in the polar solar corona. We consider that a large number of small scale shock waves can be present in the solar corona, as suggested by recent observations of polar coronal jets by the Hinode and STEREO spacecraft. The heavy ion energization mechanism is, essentially, the ion reflection off supercritical quasi-perpendicular collisionless shocks in the corona and the subsequent acceleration by the motional electric field E = - V x B. The acceleration due to the electric field is

perpendicular to the magnetic field, giving rise to large temperature anisotropy with perpendicular temperature much larger than the parallel one, which can excite ion cyclotron waves. Also, heating is more than mass proportional with respect to protons, because the heavy ion orbit is mostly upstream of the quasi-perpendicular shock foot. The observed temperature ratios between O(5+) ions and protons in the polar corona, and between alpha particles and protons in the solar wind are easily recovered. We also identify the mechanism of heavy ion reflection, which is based on ion gyration in the magnetic overshoot of the shock.

Plasma jets in the solar corona.

We have started a new research activity based on the analysis of UV data from the STEREO dual spacecraft. Preliminary analysis has led to the identification of about 80 plasma jets in the polar corona, which have been organized in a catalogue. This jets show that a substantial activity is going on even in the quiet regions. An assessment of the energetic of jets is under way. Analysis of the STEREO data has allowed to publish two catalogues of coronal hole jets, one related to polar corona jets and the other to equatorial coronal jets. The main morphological featuers of these jets have been determined, and a classification in terms of Eiffel-Tower jets, lambda-type jets, and helical structures has been proposed.

Solar activity cycle and solar neutrinos

The magnetic solar cycle consists of two components: the well-known main cycle with period around 11 yr, and a high-frequency component with period close to 2 yr, whose origin is not yet understood. The spatio-temporal dynamics of solar activity, by the means of the green coronal emission line at 530.3 nm recorded from 1939 to 2005, has been investigated by studying the main oscillations and the time evolution of the basic periods. In addition to the main 11-year periodicity, the high-frequency component has been recorded mainly on the polar regions of the Sun, thus indicating a different origin from the emergence of active regions. Evidence for variations in the period lengths of this component has been found for the first time. Our analysis shows that, unlike the main periodicity, the high-frequency component does not show the typical properties of a true mode of oscillation but seems to originate, in a narrow band of frequencies, from a stochastic superposition of different oscillators. This kind of findings can provide more constraints on dynamo models introduced to describe the different components of the solar cycle. Moreover by using several solar activity indicators such as sunspot are as fluxes of solar energetic protons and galactic cosmic rays during about 30 years we find that the quasi-biennial periodicity is also a fundamental mode. At the same time we provide evidence for the quasi-biennial modulation of the solar neutrino flux that results significantly correlated with solar activity indicators. These findings support the hypothesis of a connection between solar neutrinos and solar magnetic fields, probably through direct interaction with the neutrino magnetic moment.

Sun-Earth interactions

We studied the influence of the Sun on the climate system by investigating the seasonal oscillation of monthly averaged temperatures recorded at 1167 stations covering the whole USA. We found the presence of an orbit-climate relationship on yearly time scales. This relationship manifests itself through occasional destabilization of the phase of the seasonal component due to the local changing of balance between direct insolation and the net energy received by the Earth. We observed that the local intermittent dynamics is modulated by a periodic component due to the nutation of Earth, which represents the main modulation of the Earth's precession. The global effect in the last century results in a cumulative phase-shift of 1.7 days towards earlier seasons. From a theoretical point of view, we described the climate dynamics of the seasonal cycle through a nonlinear circle-map, so that the destabilization process can be associated to intermittent transitions from quasi-periodicity to chaos.

1.3 MAGNETOSPHERIC PHENOMENA AND NONLINEAR GEOPHYSICS

Proton acceleration in the Earth's magnetotail

Ion beams with energies of the order of several tens of keV are frequently observed in the Earth's magnetotail. We consider two possible acceleration mechanisms, the cross tail electric field Ey (due to the large-scale coupling between solar wind and magnetosphere, along dawn-dusk direction) and the stochastic acceleration due to the electromagnetic fluctuations present in the magnetotail. A 2D test particle simulation has been performed in order to reproduce the interaction between charged particles and electromagnetic fluctuations and the constant dawn-dusk electric field, Ey, in the magnetotail current sheet. Electromagnetic perturbations are generated byrandom oscillating "clouds" moving in the x-y plane (in GSM coordinate system). Protons are accelerated via a stochastic Fermi-like process and, by varying the features of the electromagnetic fluctuations, along with the value of the normal magneticcomponent and other physical parameters, we can explain a range of energetic ion observations.

The extension to 3D of the test particle simulation is under study, in order to reproduce the 3D nature of the magnetotail current sheet. The code would help to understand the acceleration and beam formation mechanisms that are at work in the magnetotail.

Two-disk dynamo models of magnetic field reversals

The Sun and the Earth possess dipolar magnetic fields that exhibit polarity reversals. Recent works, based on numerical simulations and laboratory experiments, found similar dynamical behaviours. A statistical analysis of a numerical simulation based on a generalized two-disk dynamo model has been performed. It was found that the dynamics of the system is controlled by the variations of the ratio of the torques and we observed different dynamical regimes characterized either by bursts or reversals, which can be periodic or random, of the magnetic field.

1.4 LABORATORY PLASMAS

Turbulence in laboratory magnetized plasmas

The understanding of turbulence behaviour in magnetized plasmas is of crucial importance for the use of controlled thermonuclear fusion as an energy source, given its central role in driving cross-field energy losses in magnetized plasmas. In particular, the edge region of all kinds of toroidal fusion devices (tokamaks, stellarators, reversed field pinches) is characterized by the presence of strong electrostatic fluctuations which account for most of the particle transport and which are in dynamical equilibrium with the ExB drift velocity shear. Edge turbulence in fusion devices has been shown to exhibit strong intermittency and formation of coherent structures which play a relevant role in driving energy losses. It has recently been shown that a Yaglom law for electrostatic turbulence, that is, a relation for the third–order mixed moment involving the particle number density as a passive scalar and the ExB drift velocity, can be deduced from a simple model of electrostatic fluctuations which describes bursty turbulence in plasmas. We have investigated the existence of the Yaglom law for electrostatic turbulence in laboratory magnetized plasmas for the first time. Using measurements of intermittent transport at the edge of the RFX-mod reversed field pinch plasma device, we found that the above scaling relation is nicely verified at intermediate scales of few cm. In this range of scales, that unambiguously represents the inertial range of electrostatic turbulence, we have also analysed the intermittency properties of electrostatic turbulence by measuring anomalous scaling exponents of density and velocity structure functions.

Turbulence in pure electron plasmas

Highly magnetized pure electron plasmas confined in Malmberg-Penning traps allow for the experimental study of two-dimensional fluid turbulence, when the experimental conditions are such that the cold non-relativistic guiding center approximation is valid. The dynamics of the freely decaying 2D turbulence in a pure electron plasma, produced in the Malmberg-Penning trap ELTRAP of the Plasma Physics group of Milan University has been studied experimentally and analyzed through the Proper Orthogonal Decomposition (POD) technique. It has been shown that, when the initial condition consists of an annular vorticity distribution, the POD modes with the major enstrophy content are dominated by the contribution of diocotron modes which appear to be active over the whole evolution of the plasma, i.e., during both the onset of the instability and the subsequent relaxation of turbulence.

Compressible magnetohydrodynamic simulations of the Reversed Field Pinch

A reversed field pinch is a toroidal configuration used to confine plasmas in fusion machines. The poloidal and toroidal components of the magnetic field in an RFP are mostly generated by electric currents flowing in the plasma and they are of the same order of magnitude. The configuration is characterized by a reversal of the toroidal magnetic field close to the wall. Besides the interst of this kind of machines as potential fusion reactors, they are also useful for the study of fundamental issues like plasma relaxation, plasma turbulence and its effects on plasma confinement. We studied the reversed field pinch through the numerical solution of the compressible magnetohydrodynamic equations. Two cases are investigated: In the first case the pressure is derived from an adiabatic condition and in the second case the pressure equation includes heating terms due to resistivity and viscosity. In the adiabatic case, a single helicity state is observed and the reversed field pinch configuration is formed for short time intervals and is finally lost. In the non-adiabatic case, the system reaches a multiple helicity state and the reversal parameter remains negative for a longer time. The results show the importance of compressibility in determining the large scale dynamics of the system.

The temperature evolution has been investigated in a simulation including thermal conductivity. For numerical reasons, an isotropic thermal conductivity is used, even though in a RFP plasma the parallel conductivity is much larger than the perpendicular one so that magnetic field lines tend to become isothermal. The system shows alternating multiple helicity states and quasi-single helicity states. Single-helical axis (SHAx) states are formed when the amplitude of the dominant mode is above a determined threshold, as observed in experiments. The relation between heat transport

and magnetic field topology that is observed in RFP experiments cannot be found in the simulation, since thermal conductivity is independent of the magnetic field.

1.5 COMPLEX SYSTEMS

Stochastic polarization switching in ferroelectric thin films

The repolarization phenomenon in a ferroelectric film has been investigated. The ferroelectric sample used was lead zirconate titanate (PZT) obtained by sol-gel synthesis and deposited by spin coating on ITO/glass substrate. A series of repolarizations were induced in the ferroelectric film by applying a triangular wave and the current peaks related to the switchings of the ferroelectric domains were acquired for statistical analyses. It has been shown that the dynamics and statistics of polarization switchings are well simulated by a simple mean-field model in which a double-well, asymmetric potential is included to describe the asymmetry at the PZT-ITO interface.

A PUBLICATIONS ON SCIENTIFIC JOURNALS

A.1 Publications on international journals

A.1.1 Publications on international journals printed in 2009

1. Perri S., Lepreti F., Carbone V., Vulpiani A.,
   Dynamical properties of test particles in stochastic electromagnetic fields,
   Communications in Nonlinear Science and Numerical Simulations **14**, 2347-2352 (2009)

2. Greco A., Matthaeus W. H., Servidio S., Chuychai P., Dmitruk P.,
   Statistical analysis of discontinuities in solar wind ACE data and comparison with intermittent MHD turbulence,
   The Astrophysical Journal **691**, L111-L114 (2009)

3. Califano F., Faganello M., Pegoraro F., Valentini F.,
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   Nonlinear Processes in Geophysics **16**, 1-10 (2009)

4. Vecchio, A., Cauzzi G., Reardon K. P.,
   The solar chromosphere at high resolution with IBIS II. 3-minute acoustic shocks in the quiet internetwork,
   Astron. & Astrophys. **494**, 269 (2009)

5. Perri S., Greco A., Zimbardo G.,
   Stochastic and direct acceleration mechanisms in the Earth's magnetotail,
   Geophysical Research Letters **36**, L04103- (2009)

6. Zimbardo G., Greco A., Veltri P., Voros Z., Amata E., Taktakishvili A.L., Carbone V., Sorriso-Valvo L., Guerra I.,
   Solar-Terrestrial relations: magnetic turbulence in the Earth's magnetosphere and geomagnetic activity,
   Earth Moon Planets **104**, 127-129 (2009)

7. Zimbardo G., Bitane R., Pommois P., Veltri P.,
   Kolmogorov entropy of magnetic field lines in the percolation regime,
   Plasma Physics and Controlled Fusion **51**, 015005- (2009)

8. Aburjania G. D., Chargazia Kh. Z., Zelenyi L. M., Zimbardo G.,
   Model of strong stationary vortex turbulence in space plasmas,
   Nonlinear Processes in Geophysics **16**, 11-22 (2009)

9. Perri S., Zimbardo G.,
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   Astropysical Journal Letters **693**, L118-L121 (2009)

10. Bruno R., Carbone V., Voros Z., D'Amicis R., Bavassano B., Cattaneo MB, Mura A, Milillo A, Orsini S, Veltri P., Sorriso-Valvo L., Zhang T, Biernat H, Rucker H, Baumjohann W., Jankovicova D., Kovacs P.,
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    Earth Moon Planets **104**, 101-104 (2009)

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    The Energy Cascade in Solar Wind MHD Turbulence,
    Earth Moon Planets **104**, 115-119 (2009)

12. Perri S., Yordanova E., Carbone V., Veltri P., Sorriso-Valvo L., Bruno R., André M.,
    Magnetic turbulence in space plasmas: Scale-dependent effects of anisotropy,
    Journal of Geophysical Research **114**, A02102- (2009)

13. Servidio S., Matthaeus H. W., Shay M. A., Cassak P. A., Dmitruk P.,

Magnetic Reconnection in Two-Dimensional Magnetohydrodynamic Turbulence,
Physical review Letters **102**, 115003-1-115003-4 (2009)

14. Anderegg F., Driscoll C. F., Dubin D. H. E., O'Neil T. M., Valentini F.,
Electron acoustic waves in pure ion plasmas,
Physics of Plasmas **16**, 055705- (2009)

15. Lepreti F., Carbone V., Spolaore M., Antoni V., Cavazzana R., Martines E., Serianni G., Veltri P., Vianello N., Zuin M.,
Yaglom law for electrostatic turbulence in laboratory magnetized plasmas,
Europhysics Letters **86**, 25001-p1-25001-p5 (2009)

16. Valentini F., Veltri P.,
Electrostatic Short-Scale Termination of Solar-Wind Turbulence,
Physical Review Letters **102**, 225001- (2009)

17. Greco A., Perri S., Zimbardo G., Zelenyi L. M.,
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Advances in Space Research **44**, 528-533 (2009)

18. Greco A., Matthaeus W. H., Servidio S., Dmitruk P.,
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EuroPhysics Letters **88**, 25001- (2009)

21. Onofri M., Malara F., Veltri P.,
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22. Sorriso-Valvo L., Carbone V., Bourgoin M., Odier P., Plihon ., Volk R.,
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International Journal of Modern Physics B **23**, 5483-5491 (2009)

23. Donato S., Meduri D., Lepreti F.,
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International Journal of Modern Physics B **23**, 5492-5503 (2009)

24. Lepreti F., Kossobokov V., Carbone V.,
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International Journal of Modern Physics B **23**, 5609-5618 (2009)

25. Wan M., Oughton S., Servidio S., Matthaeus W. H.,
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Physics of Plasmas **16**, 080703-1-080703-4 (2009)

26. Rodgers D. J., Servidio S., Matthaeus W. H., Montgomery D. C., Mitchell T. B., Aziz T.,
Hydrodynamic Relaxation of an Electron Plasma to a Near-Maximum Entropy State,
Physical Review Letters **102**, 244501-1-244501-4 (2009)

27. Wan M., Servidio S., Oughton S., Matthaeus W. H.,
The third-order law for increments in magnetohydrodynamic turbulence with constant shear,
Physics of plasmas **16**, 090703-1-090703-4 (2009)

28. Aburjania G., Chargazia K., Zelenyi L. M., Zimbardo G.,
Large-scale zonal flow and magnetic field generation due to drift-Alfven turbulence in ionosphere plasma,
Planetary and Space Science **57**, 1474-1484 (2009)

29. Perri S., Zimbardo G.,
Ion and electron superdiffusive transport in the interplanetary space,
Advances in Space Research **44**, 465-470 (2009)

30. Milovanov A. V., Bitane R., Zimbardo G.,
Kolmogorov-Sinai entropy in field line diffusion by anisotropic magnetic turbulence,
Plasma Physics and Controlled Fusion **51**, 075003- (2009)

31. Nistico' G., Bothmer V., Patsourakos S., Zimbardo G.,
Characteristics of EUV Coronal Jets Observed with STEREO/SECCHI,
Solar physics **259**, 87-99 (2009)

32. Artemyev A. V., Zelenyi L. M., Malova H. V., Zimbardo G., Delcourt D.,
Acceleration and transport of ions in turbulent current sheets: formation of non-maxwelian energy distribution,
Nonlinear Processes in Geophysics **16**, 631-639 (2009)

33. Dahlburg R. B., Liu J.-H., Klimchuk J. A., Nigro G.,
Explosive instability and coronal heating,,
The Astrophysical Journal, **704**, 1059-1064 (2009)

A.1.2 Publications on international journals accepted in 2009

1. Valentini F., Califano F., Veltri P.,
The kinetic nature of turbulence at short scales in the solar wind,
to appear on Nonlinear processes in geophysics.

A.1.3 Publications on international journals submitted in 2009

1. Greco A., Servidio S., Matthaeus W. H., Dmitruk P.,
Intermittent structures and magnetic discontinuities on small scales in MHD simulations and solar wind,
submitted to Planetary and Space Science.

2. Marino S., Lepreti F., Carbone V.,Scaramuzza N.,
Stochastic ferroelectric switching of lead zirconate tutanate thin films,
The European Physical Journal B

B PUBLICATIONS ON CONFERENCE PROCEEDINGS

B.1 Publications on international conference proceedings in 2009

1. Malara F., Nigro G., Veltri P.,
Energy balance and cascade in MHD turbulence in the solar corona,
in “Universal Heliophysical Processes”, proceedings of the IAU Symposium 257, N. Gopalswamy, D. Webb, Cambridge University Press, pp. 543-553 (2009)

B.2 Publications on national conference proceedings in 2009

1. Bruno R., D’Amicis R., Vannaroni G. Cattaneo M.B., Pallocchia G., Baldetti P., Morbidini A., Consolini G., Marcucci M.F., Bavassano B., Pietropaolo E., Carbone V., Sorriso-Valvo L., and Di Lellis A.M.,
Laboratory activity at INAF-IFSI in the framework of its participation to SWA onboard ESA-Solar Orbiter,
in Mem. S.A.It. Vol. 80, p. 239 (2009)

2. D'Amicis R., Bruno R., Pallocchia G., Bavassano B., Pietropaolo E., Carbone V., Sorriso-Valvo L., Marino R., *Observing MHD turbulence in the solar wind,*
in Mem. S.A.It. Vol. 80, pp. 280(2009)

B.3 Chapters in published books, published books

1. Valentini F., Onofri M., Primavera L.,
Mixed finite difference-spectral numerical approach for kinetic and fluid description of nonlinear phenomena in plasma physics,
in Numerical Simulation Research Progress, Simone P. Colombo and Christian L. Rizzo, Nova Publisher (2009)

2. Veltri P., Carbone V., Lepreti F., Nigro G.,
Self Organization in Magnetohydrodynamic Turbulence,
in Encyclopedia of Complexity and Systems Science, Meyers R. A., Springer (2009)

C INVITED PRESENTATIONS

C1. Invited presentations at international conferences in 2009

1. Valentini F., Califano F., Veltri P.,
Numerical analysis of kinetic effects on the short-scale termination of solar-wind turbulence through multi-dimensional Vlasov simulation,
Vlasovia 2009, International workshop on the theory and applications of Vlasov equations, Marseille, August 31 – September 4 2009

2. Sorriso-Valvo L.,
The turbulent cascade in solar wind MHD,
ERG, SCOPE and beyond, Fuchinobe (Japan), 2/11/2009-6/11/2009 2009

3. Valentini F.,
New insights and challenges in numerical astrophysics research: the Vlasov approach and comparison with Lagrangian PIC methods,
Simulations of complex phenomena in Astrophysics - First light after the dark ages, Spineto (SI), 07/09/-11/09 2009

4. Zimbardo G.,
Superdiffusive and subdiffusive transport of energetic particles in astrophysical plasmas: numerical simulations and experimental evidence,
Workshop on Nonlinear Dynamics and Structure Formation in Complex Systems, Frascati, 21 September-22 September 2009

C2. Invited presentations at national conferences in 2009

1. Zimbardo G.,
Ion superdiffusion at the solar wind termination shock,
Riunione ASI-ESS, Firenze, 5 febbraio-6 febbraio 2009.

2. Zimbardo G.,
A new mechanism for heating the solar corona,
53° Congresso SAIt, L'Universo quattro secoli dopo Galileo, Pisa, 4 maggio-8 maggio 2009.

D PRESENTATIONS AT CONFERENCES

D1. Presentations at international conferences in 2009

1. Valentini F., Veltri P., Califano F., Mangeney A.,
Cross-scale effects in solar wind turbulence: multi-dimensional Vlasov simulations,

Workshop on Cross-scale coupling in plasmas, Arcavacata di Rende (CS), 09/03/2009-11/03/2009

2. M. Onofri, L. Primavera, P. Veltri, F. Malara,
   Spectral anisotropy produced by the nonlinear evolution of magnetic reconnection,
   Workshop on Cross-Scale Couplings in Plasmas, Rende, 09-03-12-03 2009

3. Marino R., Sorriso-Valvo L., Carbone V., Noullez A., Bruno R.
   Solar wind turbulence: cascade, dissipation and heating,
   Workshop on cross-scale coupling in plasmas, Rende (CS), 9/3/2009-11/3/2009

4. Sorriso-Valvo L., Marino R., Carbone V., Noullez A., Bruno R.,
   The turbulent cascade in the solar wind,
   Solar Wind 12, Saint Malo, 22 june-27 june 2009

5. Malara F., Nigro G., Onofri M., Veltri P.,
   Large-scale energy balance and MHD turbulence in solar coronal structures,
   Solar Wind 12, Saint Malo, 22 june-27 june 2009

6. Sorriso-Valvo L., Marino R., Carbone V., Noullez A., Bruno R.,
   Compressive cascade in soalr wind MHD turbulence,
   rd Solar Orbiter Workshop, Sorrento, 24 May-29 May 2009

7. Lepreti F., Romé M., Pozzoli R., Vecchio A., Carbone V., Maero G., Paroli B., Valentini F.,
   Proper Orthogonal Decomposition of two-dimensional turbulence in a pure electron plasma,
   Plasmas in the Laboratory and in the Universe: interactions, patterns, and turbulence, Como, 01/12/2009-04/12/2009 2009

8. Sorriso-Valvo L., Marino R., Carbone V., Bruno R., and Noullez A.,
   The mixed third-order structure functions in the solar wind: convergence and scaling,
   European Geosciences Union General Assembly 2009, Vienna, 19/04/2009-24/09/2009

9. M. Onofri, F. Malara, P.Veltri,
   Effects of heating and density fluctuations in magnetohydrodynamics models of the reversed-field pinch,
   11th Easter Plasma Meeting on Magnetic reconnection and turbulence in fusion relevant plasmas, Torino, april 15 – april 17, 2009

10. Greco A., Servidio S., Matthaeus W. H.,
    Intermittent structures and magnetic discontinuities in MHD turbulence and solar wind,
    CROSS SCALE workshop, Universita' della Calabria- Rende (CS) - Italy, March 9 – 11, 2009

11. Greco A., Perri S., Zimbardo G.,
    Competition between stochastic and direct acceleration mechanisms in the Earth's magnetotail,
    CROSS SCALE workshop, Universita' della Calabria- Rende (CS) - Italy, March 9 – 11, 2009

12. Greco A., Matthaeus W. H., Servidio S., Dmitruk P., Wan M., Oughton S., Chuychai P.,
    Statistical properties of solar wind discontinuities, intermittent turbulence, and rapid emergence of non-Gaussian distributions,
    12th International Solar Wind Conference, Saint-Malo Francia, 21 Giugno-26 Giugno 2009

13. Dalena S. , Greco A. , Zimbardo G.,
    Influence of magnetic turbulence on ionospheric O+ and H+ ions dynamic in the near-Earth magnetotail,
    17th Cluster Workshop, Uppsala Svezia, May 12 -15, 2009

14. S. Servidio, W. H. Matthaeus, P. Cassak, M. Shay, P. Dmitruk,
    Statistical Properties of Magnetic Reconnection in MHD turbulence,
    American Physical Society, 51st Annual Meeting of the APS Division of Plasma Physics, November 2-6, 2009, Atlanta, Georgia (USA), November 2-6, 2009

15. D. Rodgers, S. Servidio, W. H. Matthaeus, T. Mitchell,

Self-Similar Decay of Enstrophy in an Electron Plasma,
51st Annual Meeting of the APS Division of Plasma Physics, Atlanta, Georgia (USA), 2 November-6 November 2009

16. D. Rodgers, S. Servidio, W. H. Matthaeus, D. Montgomery, T. Mitchell,
Characterization of Meta-Stable Equilibria of a Electron Plasma: Relaxation Towards Minimum Enstrophy and Maximum Entropy States, American Physical Society, 51st Annual Meeting of the APS Division of Plasma Physics, Atlanta, Georgia (USA), 2 November-6 November 2009

17. L. Sorriso-Valvo, R. Marino, S. Servidio, R. Bruno, A. Noullez, V. Carbone
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18. T. N. Parashar, M. A. Shay, S. Servidio, W. H. Matthaeus, B. Breech ,
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The third-order law for magnetohydrodynamic turbulence with constant shear,
American Geophysical Union, Fall Meeting, San Francisco - CA (USA), - 2009

20. W. H. Matthaeus, M. Wan,S. Servidio, S. Oughton,
Generation of non-Gaussian statistics and coherent structures in ideal magnetohydrodynamics,
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21. D. Rodgers, S. Servidio, W. H. Matthaeus, D. Montgomery, T. Mitchell, T. Aziz,
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American Geophysical Union, Fall Meeting, San Francisco - CA (USA), - 2009

22. M. Wan, S. Oughton, S. Servidio, W. H. Matthaeus,
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Twelfh International Solar Wind Conference, Saint Malo (France), 21 June-26 June 2009

23. W. H. Matthaeus, S. Servidio,P. Dmitruk,
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Twelfh International Solar Wind Conference, Saint Malo (France), 21 June-26 June 2009

24. S. Servidio, M. A. Shay, W. H. Matthaeus, P. Dmitruk, P. A. Cassak, M. Wan,
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25. T. N. Parashar, S. Servidio, M. A. Shay,W. H. Matthaeus, P. A. Cassak,
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26. Zimbardo G.,
Heavy ion reflection and heating by collisionless shocks in the solar corona: Cross-Scale contribution,
Workshop on Cross-Scale Coupling in Plasmas, University of Calabria, Rende (CS), 9 marzo-11 marzo 2009

27. Zimbardo G.,
More than mass proportional heating of heavy ions by quasi-perpendicular collisionless shocks in the solar corona,
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28. Nistico' G., Bothmer V., Patsourakos S., Zimbardo G.,
Observational features of EUV polar and equatorial coronal jets with STEREO/SECCHI,
STEREO-3 / SOHO-22: Three eyes on the Sun, Bournemouth, England, april 27 – may 1, 2009

29. Zimbardo G.,
More than mass proportional heating of heavy ions by collisionless quasi-perpendicular shocks in solar corona,
Twelfh International Solar Wind Conference, Saint Malo (France), 21 June-26 June 2009

30. Zimbardo G., Perri S.,
Superdiffusive transport upstream of the solar wind termination shock,
Twelfh International Solar Wind Conference, Saint Malo (France), 21 June-26 June 2009

31. Zimbardo G.,
Supercritical collisionless shocks as a mechanism for preferential heating in coronal holes,
AGU Fall Meeting, San Francisco, 14 December-18 December 2009

32. Lepreti F., Reardon K., Carbone V., Vecchio A.,
Turbulence and Intermittency in the Solar Chromosphere,
Third Solar Orbiter Workshop, Sorrento, may 25 -29, 2009

33. Lepreti F., Reardon K., Carbone V., Vecchio A.,
Turbulence and Intermittency in the Solar Chromosphere,
American Geophysical Union Fall Meeting, San Francisco (U.S.A.), december 14 – 18, 2009

34. Klimchuk J. A., Nigro G., Dahlburg R. B., Antiochos S. H.,
The existence and origin of turbulence in solar active regions,
American Geophysical Union Fall Meeting, San Francisco (U.S.A.), december 14 – 18, 2009

2. THEORETICAL PARTICLE PHYSICS AND APPLICATIONS

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Introduction

The research activity during the AA 2008-09 included the following subjects:

- phenomenology of hadron collisions and Quantum Chromodynamics (QCD) in the high-energy limit;

- non-perturbative properties of gauge theories discretized on a space-time lattice;
- field theory of correlated devices;
- integrability in the N=4 supersymmetric Yang-Mills theory
- physics of kaon-nucleon interactions.

A major part of this activity has been carried on in collaboration with other research groups in Italy and abroad. For the part concerning the non-perturbative study of gauge theories on a space-time lattice, a large use has been done of the PC farm "Majorana" of the Istituto Nazionale di Fisica Nucleare (INFN) – Gruppo Collegato di Cosenza, hosted by the Physics Department.

2.1 QCD IN THE REGGE LIMIT AND HADRON PHENOMENOLOGY

2.1.1 QCD in the Regge limit

It has been shown that, in the case of the forward scattering, the most part of the difference between the Möbius form of the Balitsky-Fadin-Kuraev-Lipatov (BFKL) kernel and the Balitsky-Kovchegov (BK) kernel in the next-to-leading (NLO) order can be eliminated by the transformation related to the choice of the energy scale in the representation of scattering amplitudes. The change of the nonforward BFKL kernel under this transformation has been derived as well. The functional identity of the forward BFKL kernel in the momentum and Möbius representations in the leading order has been shown and its NLO validity in N=4 supersymmetric Yang-Mills theory has been proved. Moreover, it has been demonstrated that the ambiguity of the low-x evolution kernels in NLO permits one to match the Möbius form of the BFKL kernel and the kernel of the colour dipole model and to construct the Möbius invariant NLO BFKL kernel in N=4 supersymmetric Yang-Mills theory.

Work is in progress on the calculation in the next-to-leading approximation of the double differential cross section for inclusive production of two Mueller-Navelet jets in the proton-proton collision by using the BFKL approach. Similarly we plan to consider the inclusive production of two hadrons with high transverse momentum in proton-proton collisions with "Mueller-Navelet" kinematics.

The renormalization-group properties and various evolution equations of the unintegrated (transverse-momentum dependent) parton densities, or distribution functions (TMD PDFs), have been studied in non-covariant axial light-cone gauges with different extra pole prescriptions (with special attention given to the Mandelstam-Leibbrandt gauge). A generalized renormalization procedure of TMD PDFs, as well as the modified definition which is free of additional undesirable UV divergences has been proposed, relying upon the renormalization of contour-dependent operators with obstructions. Relationship to the problems of complete gauge invariance of unintegrated parton densities and factorization in the semi-inclusive processes, like SIDIS or Drell-Yan, has been also analyzed within this approach. The work on more phenomenological issues is in progress.

2.1.2 Hadron Phenomenology

The non-conservation of charmed-strange current in the neutrino deep inelastic scattering (vDIS) strongly affects the longitudinal structure function, F_L, at small values of Bjorken x. The corresponding correction to F_L is a higher twist effect enhanced at small-x by the rapidly growing gluon density factor. As a result, the component of F_L induced by the charmed-strange current prevails over the light-quark component and dominates $F_L = F_L^{cs} + F_L^{ud}$ at $x \leq 0.01$ and $Q^2 \sim m_c^2$. The color dipole analysis clarifies the physics behind the phenomenon and provides a quantitative estimate of the effect.

The asymptotic freedom is known to split the leading-log BFKL pomeron into a series of isolated poles in the complex angular momentum plane. One of the earlier findings was that the subleading hard BFKL exchanges decouple from such experimentally important observables as small-x charm, F_L^c, and the longitudinal, F_L, structure functions of the proton at moderately large Q^2. For instance, the precocious BFKL asymptotics of $F_L^c(x,Q^2)$ was predicted with intercept of the rightmost BFKL pole $\alpha_{Pom}(0)-1=\Delta_{Pom} \sim 0.4$.

The small-x open beauty photo- and electro-production probes the vacuum exchange for much smaller color dipoles which entails significant subleading vacuum pole corrections to the small-x behavior. In view of the accumulation of the experimental data on small-x F_2^c, F_2^b and F_L we extend our early predictions to the kinematical domain covered by new HERA measurements. Our parameter-free results agree well with the determination of F_2^c, F_L and published H1 results on F_L^b, but slightly overshoot the very recent (2008, preliminary) H1 results on F_L^b.

The following effects in the nearly forward ("soft") region of the LHC are proposed to be investigated:

1) At small $|t|$ the fine structure of the cone (Pomeron) should be scrutinized: a) a break of the cone near $t \sim 0.1$ GeV^2, due to the two-pion threshold, and required by t-channel unitarity, is expected, and b) possible small-period oscillations between $t=0$ and the dip region.

2) In measuring the elastic pp scattering and total pp cross section at the LHC, the experimentalists are urged to treat the total cross section , the ρ ratio, the forward slope B and the luminosity as free parameters, and to publish model-independent results on dN/dt.

3) Of extreme interest are the details of the expected diffraction minimum in the differential cross section. Its position, expected in the interval $0.4<-t<1$ GeV^2 at the level of about 10^{-2} mb GeV^{-2} -- 10^{-1} mb GeV^{-2}, cannot be predicted unambiguously, and its depth, i.e. the ratio of $d\sigma/dt$ at the minimum to that at the subsequent maximum (about $-t=5$ GeV^2 , which is about 5, is of great importance.

4) The expected slow-down with increasing $|t|$ of the shrinkage of the second cone (beyond the dip-bump), together with the transition from an exponential to a power decrease in $-t$, will be indicative of the transition from "soft" to "hard" physics. Explicit models are proposed to help in quantifying this transition.

5) In a number of papers a limiting behavior, or saturation of the black disc limit (BDL) was predicted. This controversial phenomenon shows that the BDL may not be the ultimate limit. Exclusive J/Psi electroproduction is studied in the framework of the analytic S-matrix theory. The differential and integrated elastic cross sections are calculated using the Modified Dual Amplitude with Mandelstam Analyticity (M-DAMA) model. The model is applied to the description of the available experimental data and proves to be valid in a wide region of the kinematical variables s, t and Q^2. Our amplitude can be used also as a universal background parametrization for the extraction of tiny resonance signals.

2.2 LATTICE GAUGE THEORIES

2.2.1 Finite density QCD

The method of analytic continuation from imaginary to real chemical potential for the study of the QCD phase diagram on the temperature - baryon density plane can be tested in gauge theories free of the sign problem, such as 2-color QCD and finite isospin QCD, by means of Monte Carlo numerical simulations. In these theories it is possible to compare the predictions from the analytic continuation with the results of Monte Carlo simulations carried on directly at real chemical potential. In 2009 we performed a careful numerical study of the systematic effects involved in the determination of the critical line at real baryonic chemical potential by analytic continuation from results obtained at imaginary chemical potentials. By considering both two-color QCD with finite baryonic density and three-color QCD with finite isospin chemical potential, we found that non-linear terms in the dependence of the pseudo-critical couplings on μ^2 (μ is the chemical potential) cannot be neglected in the extrapolation from imaginary to real chemical potential, but these terms are very difficult to detect numerically and call for a high accuracy in the Monte Carlo simulation.

Work is in progress on the study of the same phenomenon in finite density QCD with four degenerate flavors.

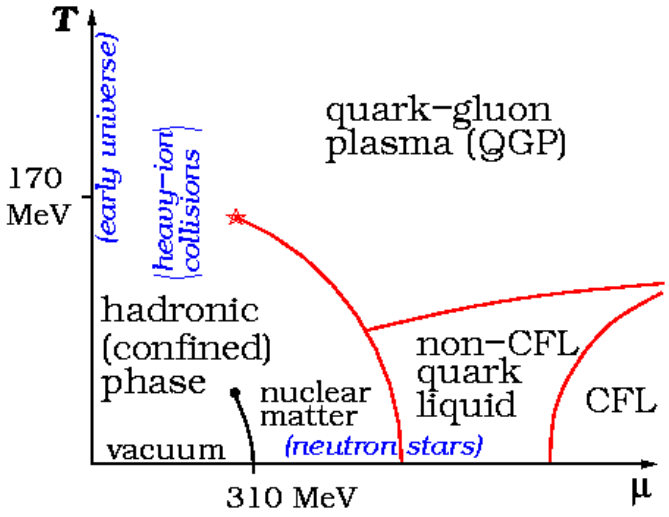

Figure 1: QCD phase diagram on the baryon chemical potential - temperature plane

2.2.2 QCD flux tubes and deconfinement transition

The confinement mechanism based on the hypothesis of QCD vacuum as dual superconductor brings along the formation of flux tubes of the chromoelectric field between static color sources (dual Meissner effect). We are studying

by Monte Carlo numerical simulations some relevant parameters of a flux tube, such as the space distribution of the field amplitude and the London penetration length. Such kind of study has been already performed in pure gauge SU(2) by the groups of Bari and Pisa a few years ago and lies on the evaluation of the vacuum expectation value of a gauge-invariant operator made of a plaquette and a Wilson loop connected by Schwinger lines. We are extending this study to the case of pure gauge SU(3).

2.2.3 Confinement and deconfinement in other gauge theories

We are studying of the deconfinement transition in compact 3d U(1) gauge theory at finite temperature. Universality arguments support the conjecture that the this transition is of Berezinsky-Kosterlitz-Thouless (BKT) type. A first step in the proof of this conjecture has been carried on last year, when it was shown numerically that the transition is compatible with BKT in the theory with zero coupling between spatial plaquettes. Work is in progress for the extension of this study to the theory in its general form and a paper will come out soon.
Similar considerations can be done for the 2d Z(N) gauge theory for N>4, where two phase transitions exist, a first order transition of order/disorder type and a BKT one. Owing to universality, both transitions should occur also in the 3d SU(N) gauge theory at finite temperature.

2.2.4 Two-dimensional spin models with a theta-term

The method of analytic continuation can be used also to study gauge theories and spin models in presence of a topological theta-term: simulations can be done at imaginary theta, where the Euclidean action is real and the Monte Carlo sampling is well-defined, and results are extrapolated to real theta.

This method has been used to verify the Haldane conjecture on the vanishing of the mass gap in the non-linear 2d O(3) sigma model at theta=π. Work is in progress on the application of this method to study possible excited states in the region of real theta, recently conjectured by Controzzi and Mussardo.

2.3 FIELD THEORY OF CORRELATED DEVICES

2.3.1 Frustration of decoherence in Y-shaped Josephson junction networks

Boundary conformal field theory techniques have been employed to show that a finite coupling IR stable fixed point arises in the phase diagram of a Y- shaped superconducting Josephson network. Near by the finite coupling fixed point, the network works as a two-level quantum systems, with reduced entanglement with the environment.

It has also been shown the relevance of the Y-shaped network for engineering highly quantum coherent finite-size superconducting devices with, as well as to estimate the values of the parameters of the device lying within a range experimentally accessible.

2.3.2 4e superconductivity in Josephson junction networks

It has been shown that pairing of Cooper pairs (and, thus, 4e superconductivity) may be induced as a result of local embedding of a quantum impurity in a Josephson network, made with pertinently designed quantum junctions. The device may be effectively described with a boundary double Sine-Gordon model, which provides an accurate description of the dc Josephson current patterns, as well as of the stable phases accessible to the network. Tunneling of pairs of Cooper pairs appears to be robust against quantum fluctuations, as a consequence of the time reversal invariance, arising when the central region of the network is pierced by a dimensionless magnetic flux $\Phi = \pi$. For $\Phi = \pi$, a stable attractive finite coupling fixed point emerges in the phase diagram of the system, near which the device has been shown to work as a two level quantum system with enhanced coherence.

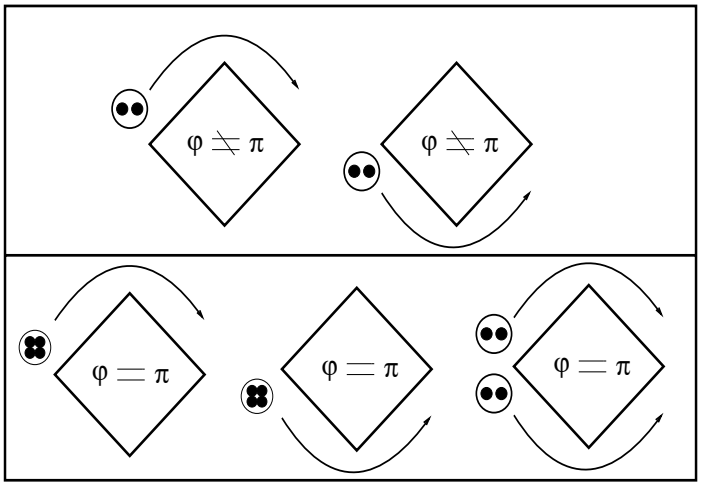

Figure 2: (Top) Tunneling of a single Cooper pair across an impurity in a Josephson network; (bottom) coherent tunneling of pairs of Cooper pairs across the same device.

2.3.3 Entanglement properties of the Haldane-Shastry spin chain

The entanglement properties of the ground state of a spin-1/2 spin chain with $1/r^2$-interaction (Haldane-Shastry model) have been investigated, in the presence of an applied magnetic field. Having explicitly constructed the ground spin for the chain with a finite number of sites N, various estimates of the entanglement have been computed at zero temperature, resorting afterwards to the thermodynamic limit ($N \to \infty$).

The results about the behavior of the quantum correlations in the system have been related with the condensation of spin-1/2 "fractionalized" excitations (spinons), occurring when the applied field reaches its saturation value.

2.4 INTEGRABILITY IN THE N=4 SUPERSYMMETRIC YANG-MILLS THEORY (SYM)

The research activity developed on two subjects.

The first one was the study of high spin behaviour of anomalous dimensions in the planar sl(2) sector of N=4 SYM. This was done using the integrability properties of this problem, in specific the mapping of the dilatation operator to the Hamiltonian of a quantum integrable model, completely defined by a set of Bethe equations. This mapping is exact for long operators, but in general is affected by the so-called wrapping problem.

The high spin anomalous dimension at fixed twist was studied, both in its first subleading dependence on the spin (the so-called virtual scaling function) and in all the sublogarithmic corrections. In parallel, the scaling limit in which both the logarithm of the spin and the twist go to infinity, while their ratio is kept constant, was studied in a systematic way, taking care of the complete subleading dependence on the inverse logarithm of the spin.

The second subject of investigation concerns the recently discovered formulation of the problem of computing anomalous dimensions in N=4 SYM in terms of a set of Thermodynamic Bethe Ansatz equations. This allows to overcome the 'wrapping' problem plaguing the previously described Bethe Ansatz equations and thus gives exact results. At present, work is still in progress and no papers have been written.

2.5 PHYSICS OF KAON-NUCLEON INTERACTIONS

We continued the revision of the programs of analysis of low-energy Kaon-Nucleon reactions. A new analysis will include results from KLOE, and hopefully from this experiment new data will be provided for low energy KN reactions, improving considerably the knowledge of this interaction. A poster about this perspectives has been submitted to a Conference in Tsukuba. Some progress has been made, though the situation is not definite about including in the group an UNICAL Ph D student and some foreign student (in particular from Iran). We are still considering the possibility of an ambitious publication on KN physics with a contribution of all the members of INFN Project PG 21.

A PUBLICATIONS ON SCIENTIFIC JOURNALS

A.1 Publications on international journals

A.1.1 Publications on international journals printed in 2009

1. V.S. Fadin, R. Fiore, and A.V. Grabovsky,
   On the discrepancy of the low-x evolution kernels,
   Nucl. Phys. B 820 (2009) 334.

2. I.V. Anikin, I.O. Cherednikov, N.G. Stefanis, and O.V. Teryaev,
   Duality between different mechanisms of QCD factorization in gamma-gamma collisions*,
   Eur. Phys. J. C61 (2009) 357.

3. N.G. Stefanis, I.O. Cherednikov,
   Renormalization-group anatomy of transverse-momentum dependent parton distribution functions in QCD,
   Mod. Phys. Lett. A24 (2009) 2913.

4. I.O. Cherednikov, N.G. Stefanis,
   Renormalization-group properties of transverse-momentum dependent parton distribution functions in the light-cone gauge with the Mandelstam-Leibbrandt prescription,
   Phys. Rev. D80 (2009) 054008.

5. R. Fiore, V.R. Zoller,
   Higher twist effects in charmed-strange vDIS diffraction,
   Phys. Lett. B681 (2009) 32.

6. R. Fiore, N.N. Nikolaev, V.R. Zoller,
   *The BFKL-Regge factorization and F(2)**b, F(2)**c, F(L) at HERA: Physics implications of nodal properties of the BFKL eigenfunctions*,
   JETP Lett. 90 (2009) 319.

7. R. Fiore, L.L. Jenkovszky, R. Orava, E. Predazzi, A. Prokudin, and O. Selyugin,
   Forward Physics at the LHC; Elastic Scattering,
   Int. J. Mod. Phys. A24 (2009) 2551.

8. R. Fiore, L.L. Jenkovszky, V.K. Magas, S. Melis, A. Prokudin,
   Exclusive J/Psi electroproduction in a dual model,
   Phys. Rev. D80 (2009) 116001.

9. P. Cea, L. Cosmai, M. D'Elia, C. Manneschi and A. Papa,
   Analytic continuation of the critical line: suggestions for QCD,
   Phys. Rev. D80 (2009) 034501.

10. D. Giuliano, P. Sodano,
    Y-junction of superconducting Josephson chains,
    Nucl. Phys. B811 (2009) 395.

11. D. Giuliano, P. Sodano,
    Pairing of Cooper pairs in a Josesphon network containing an impurity,
    EPL 88 (2009) 17012.

12. D. Bombardelli, D. Fioravanti, M. Rossi,
    Large spin corrections in N = 4 SYM sl(2): Still a linear integral equation,
    Nucl. Phys. B810 (2009) 460.

13. D. Fioravanti, P. Grinza, M. Rossi,
    Strong coupling for planar N=4 SYM theory: an all-order result,
    Nucl. Phys. B810 (2009) 563.

14. D. Fioravanti, P. Grinza, M. Rossi,
The generalised scaling function: a systematic study,
JHEP11 (2009) 037.

15. D. Fioravanti, P. Grinza, M. Rossi,
Beyond cusp anomalous dimension from integrability,
Phys. Lett. B675 (2009) 137.

16. D. Fioravanti, G. Infusino, M. Rossi,
On the high spin expansion in the sl(2) N=4 SYM theory,
Nucl. Phys. B822 (2009) 467.

A.1.2 Publications on international journals accepted in 2009

1. D. Giuliano , A. Sindona, G. Falcone, F. Plastina and L. Amico,
Entanglement in spin system with inverse-square statistics interaction,
to appear in New Journal of Physics.

B PUBLICATIONS ON CONFERENCE PROCEEDINGS

B.1 Publications on international conference proceedings in 2009

1. S. Fazio, R. Fiore, L.L. Jenkovszky,
Deeply virtual Compton scattering and generalized parton distributions,
AIP Conf. Proc. 1105, 226-230 (2009).

2. V.K. Magas, R. Fiore, L.L. Jenkovszky, A. Prokudin,
J/Psi photo- and electroproduction in a dual model,
AIP Conf. Proc. 1105, 244-247 (2009).

3. R. Fiore and V. R. Zoller,
Current non-conservation effects in vDIS diffraction,
AIP Conf. Proc. 1105, 304-307 (2009).

4. I.O. Cherednikov and N.G. Stefanis,
TMD PDF's: gauge invariance, RG properties and Wilson lines,
AIP Conf. Proc. 1105, 327-330 (2009).

5. P. Cea, L. Cosmai, M. D'Elia and A. Papa,
Analytic continuation in two-color QCD: new results on the critical line,
Nucl. Phys. A820 (2009) 239C [presented at International Conference on Strong and Electroweak matter (SEWM 2008), Amsterdam, The Netherlands, 26-29 Aug 2008.]

6. P. Cea, L. Cosmai, M. D'Elia, C. Manneschi and A. Papa,
On the analytic continuation of the critical line,
PoS(LAT2009)161 [contribution to the proceedings of "Lattice 2009", The XXVII International Symposium on Lattice Field Theory Beijing, July 26-31, 2009.]

7. P. Cea, L. Cosmai, M. D'Elia and A. Papa
Analytic continuation in QCD-like theories at finite density and finite isospin,
PoS(LAT2009)192 [contribution to the proceedings of "Lattice 2009", The XXVII International Symposium on Lattice Field Theory Beijing, July 26-31, 2009.]

C PRESENTATIONS AT SCHOOL AND CONFERENCES

C.1 Presentations at international schools and conferences in 2009

1. P. Cea, L. Cosmai, M. D'Elia, C. Manneschi and A. Papa,
On the analytic continuation of the critical line,

presented by A. Papa at "Lattice 2009", The XXVII International Symposium on Lattice Field Theory Beijing, July 26-31, 2009

2. P. Cea, L. Cosmai, M. D'Elia and A. Papa
   Analytic continuation in QCD-like theories at finite density and finite isospin,
   presented by L. Cosmai at "Lattice 2009", The XXVII International Symposium on Lattice Field Theory Beijing, July 26-31, 2009.

3. I.O. Cherednikov,
   On the Q2-evolution of the transverse-momentum dependent parton densities",
   given at the International Workshop "Transverse Partonic Structure of Hadrons", 21-26 June 2009, Yerevan.

4. I.O. Cherednikov,
   Anomalous dimensions and evolution equations of unintegrated parton densities,
   given at the Helmholtz International School-Workshop "Calculations for Modern and Future Colliders", 10-20 July 2009, Dubna.

5. I.O. Cherednikov,
   Transverse-momentum dependent parton densities: evolution equations,
   given at the Low-X Meeting, 8-13 Sept 2009, Ischia, Italy

6. I.O. Cherednikov,
   Factorization in semi-inclusive processes: TMD approach,
   invited talk given at the VIII European Research Conference "Electromagnetic Interactions with Nucleons and Nuclei", Sept. 27 - Oct. 2, 2009, Milos Island, Greece

7. I.O. Cherednikov,
   Transverse-momentum dependent densities in the light-cone gauge: definition, renormalization and evolution,
   invited talk given at the International Conference ``Orbital Angular Momentum of Partons in Hadrons", Nov. 9-13, 2009, Trento, Italy

EDITORSHIP OF CONFERENCE PROCEEDINGS IN 2009

1. R. Fiore, I. Ivanov, A. Papa, J. Soffer,
   Diffraction in high-energy physics,
   Proceedings, International Workshop, Diffraction 2008, La Londe-les-Maures, France, September 9-14, 2008.
   Published in AIP Conf. Proc. 1105 (2009), 417 pages.

ORGANIZATION OF INTERNATIONAL CONFERENCES IN 2009

1. Low-x Meeting 2009,
   Forio d'Ischia, 8-13 September 2009, organized by R. Fiore and A. Papa (Univ. Calabria), Ch. Royon (Saclay, France) et al., http://www-d0.fnal.gov/~royon/lowx_italy/

3. EXPERIMENTAL PARTICLE PHYSICS

Professors and Researchers M. Capua
G. Crosetti
L. La Rotonda
A. Mastroberardino
M. Schioppa
G. Susinno
E. Tassi

Postdoc fellows C. Adorisio
S. Fazio
D. Salvatore

PhD students V. Lavorini
G. Morello
T. Venturelli

Technicians: F. Pellegrino, V. Romano, P. Turco

Experimental particle physics studies the fundamental constituents of matter and the forces that cause their mutual interactions. Studies in experimental energy physics are made by means of particle accelerators and particle detectors. The first ones rise the energy of beam particles (in the most powerful accelerators the energy can reach values as large as a few TeV) and allow them to collide against each other or a target. The detectors are designed to reconstruct the particles produced as a consequence of the primary particle interactions. The need of innovative tools from the technological point of view has wide implications in many areas of applied physics.

The researches on high energies physics to which the physicists of this University take part are:

2. Study of the proton structure in deep inelastic scattering processes with the ZEUS experiment at the lepton-proton accelerator HERA of the DESY Laboratory (Hamburg, Germany).
3. Study of proton-proton interactions with the ATLAS experiment at the LHC accelerator of the CERN laboratory (Geneva, Switzerland).
4. Studies of a forward physics detector for ATLAS (AFP) and medical applications.
5. Hadronic calorimetry: analysis and development of hadronic calorimeter modules based on the Dual Readout Method (DREAM).
6. Study of the electron-positron interactions at the centre of mass energy 1020MeV with KLOE apparatus at DAFNE collider (Frascati, Italy).
7. Project for the realization of a ground-based apparatus to detect the muon content of the showers employing the last generation high precision drift chamber (UNICAL, Italy).

3.1 THE ZEUS EXPERIMENT AT THE HERA E-P COLLIDER (DESY, HAMBURG-GERMANY)

Physicists: M. Capua
S. Fazio
A. Mastroberardino
M. Schioppa
G. Susinno
E. Tassi

Technicians: F. Pellegrino

International collaboration

ZEUS is a collaboration running a large particle detector at the electron-proton collider, HERA, at the DESY laboratory in Hamburg. The participating scientists are pushing forward our knowledge of the fundamental particles and forces of nature, gaining unsurpassed insight into the exciting laws of the microcosm.
The ZEUS detector is a sophisticated tool for studying the particle reactions provided by the high-energetic beams of the HERA collider. At the HERA collider two separate magnet systems guide the e and p beams around the 6,3 km long

ring and two independent superconducting RF systems accelerate the e and p bunches up to 30GeV and 920GeV energy respectively.

The High Energy Experimental Physics (HEP) group of the UNICAL has been involved in the ZEUS Collaboration, since 1988, in the design, construction, testing, calibration, alignment, running and maintenance of three components of ZEUS experiment: Forward Muon Spectrometer (FMUON), Leading Proton Spectrometer (LPS) and MicroVertex (MVD). Furthermore the UNICAL HEP researchers participate, since 1991 when the detector started operating, to the data taking as well as the physics analyses.

At the maximum beam energies the centre of mass energy is ~314GeV, much larger than previously achieved in such collisions, and allowing to probe the proton structure down to distance scales as low as 10^{-18}m which is a factor 1000 smaller than the proton radius. With this resolving power exciting physics topics can be studied, such as proton structure, neutral and charged current processes, tests of Quantum Chromodynamics, studies of diffraction and for new particles. At large momentum transfers (the kinematical limit at HERA is 10^5 GeV^2/c^2) there is a direct interaction of the electron with one of the quarks in the proton, while the "remnant" of the proton are only slightly involved. For this reason HERA is often addressed as the world's only lepton-quark collider.

New ZEUS results are in progress and the UNICAL members of the Collaboration are actively involved; during the 2009 year we have continued to contribute to:

- the combination of the ZEUS and H1 inclusive results and determination of the proton parton distribution functions;
- the studies of Deeply Virtual Compton Scattering in diffractive processes with the complete HERA data set.

One of the most important goal of the HERA research program is to capitalize the experience gained in the study of inclusive and diffractive processes and apply it to future measurements at the LHC experiments.
The physics coordinator of the experiment for the year 2009 has been a member (E.T.) of our group.

3.2 ATLAS EXPERIMENT AT THE LHC PROTON-PROTON COLLIDER (Geneva – Switzerland)

Physicists: G. Crosetti
M. Capua
S. Fazio
L. La Rotonda
V. Lavorini
A. Mastroberardino
E. Meoni
G. Morello
D. Salvatore
M. Schioppa
G. Susinno
E. Tassi
T. Venturelli

Technicians: F. Pellegrino, V. Romano, P. Turco

International collaboration

Nature has given us more than one elementary particle (6 leptons, 6 quarks and the carriers of the four fundamental interactions), whose masses range in a wide interval of values from the mass-less gauge bosons to the top quark mass, M_t=170 GeV/c^2. The mechanism that determines the particle masses is still unknown and many experiments with particle accelerator have been undertaken to give an insight into it and explain the mass origin.

In 1964 Peter Higgs first proposed a clever solution to this puzzle: an undetectable field, similar to the electromagnetic one,

permeates the whole space. As particles move in space they travel through this field, and interaction with this field allows them to acquire their masses. This is similar to the action of viscous forces felt by particles moving through any thick liquid: the stronger the interaction of the particles with the field, the bigger the mass they seem to have. We know from quantum theory that fields have particles associated with them, so a Higgs boson should be associated to the Higgs field.

Up to now no one has ever observed the Higgs boson in an experiment to confirm the theory. Finding this particle would give an insight into why particles have certain mass, and help to develop subsequent physics. The technical problem is that we do not know the mass of the Higgs boson itself, which makes it more difficult to identify. Physicists have to look for it by systematically searching a range of mass within which it is predicted to exist. The yet unexplored range is accessible using the Large Hadron Collider (LHC).

This collider provides 10 times higher center of mass energy and 100 times higher p-p collision rates than previous colliders and is fully operative since November 2009. This opens up a new frontier of physics and the LHC experiments, ATLAS, CMS, ALICE and LHCb, are ready to explore this great potential.

ATLAS is a general-purpose experiment. Designed to see a wide range of particles and phenomena produced in LHC collisions, it involves approximately 2,000 physicists from some 35 countries. These scientists use the data collected from the complex detectors to search for new phenomena, including the Higgs boson, super-symmetry and extra dimensions. They also measure the properties of previously-discovered quarks and bosons with unprecedented precision, and are on the lookout for completely new, unpredicted phenomena.

The basic design concept to achieve these goals includes three detector systems:

Inner Tracker, with semiconductor pixel and strip detectors for very high accuracy measurements of the charged particle trajectories, followed by straw tube detectors giving independent electron identification. The tracker is confined to a cylinder 6.8 m long and with a radius of 1.1 m in a 2 T magnetic field, provided by a superconductive solenoid

Calorimeter, with an inner cylinder in highly granular liquid argon technology with Pb absorber, followed at large radius by an iron-tile scintillator calorimeter providing good resolution in a very cost-effective manner

High precision standalone **Muon Spectrometer**. Its conceptual layout is based on the magnetic deflection of muon track in a system of three large superconducting air-core toroid magnets instrumented with separate-function trigger and high-precision tracking chambers.

The researchers of the experimental high energy physics (HEP) group of UNICAL have been strongly involved in various aspects of the design, construction, installation and test of the muon spectrometer since 1994. During this period the contribution from many undergraduate, graduate and PhD students and postdoc researchers has been substantial to this end.

Our group is also involved in the design and simulation of the ATLAS Forward Physics (AFP) apparatus. The AFP is a proposed project which comprises a new generation of 3D silicon detectors, to be inserted along the beam pipe, at a distance of 220 m and 420 m from the interaction point. The installation of the detectors will allow the ATLAS experiment to study diffractive processes including the very important diffractive production of the Higgs boson.

During 2009 the Unical HEP group gave a major contribution to many ATLAS activities:

- Participation in the maintenance and improvement task force of the muon precision chambers at CERN. This is a small

group of expert physicists taking care of the whole detector performance, overlooking the functionality of gas, readout, alignment, data control, high and low-voltage systems

- Maintenance and development of the low-level data acquisition software for the ATLAS sub-detector online monitoring system, GNAM. The Cosenza HEP group has developed the GNAM tool during the installation and commissioning phase of the ATLAS muon spectrometer in order to reveal any problem in the detector promptly, such as inefficient or dead channels that may affect the data taking and the subsequent reconstruction and pattern recognition processes. This tool, highly appreciated during the commissioning operations, has been then inserted into the official ATLAS software system and is widely used in data-taking

- Two test beams at CERN facilities designed to characterize prototypes of the silicon detector. In collaboration with colleagues from Messina University we are exploiting the 3D silicon detector technology to develop new dosimeters for medical applications.

- Contribution to the Standard Model (SM) physics group studying top quark production. The top quark, the heaviest of all known elementary particles, was discovered in 1995 at the Fermilab Tevatron collider.

Studying top quarks is important for several reasons. With its large mass, the top quark is the only fermion on the electroweak scale. It is therefore of great interest for the studies of electroweak symmetry breaking. Accurately measuring the top quark mass also helps put constraints on the SM Higgs boson mass. Additionally, top quarks will constitute a significant background process to many beyond SM searches.

The analysis carried out by our group studied top pair production with decay in the semileptonic mode, where events in the electron plus jets channel are isolated.

- Studies of W and Z decay in muon channel in ATLAS detector, useful to verify the detector response and perform first inclusive cross section measurement.

- Contribution to the Long-Lived particle and Hidden Valley group and Exotics physics group.

Several extensions of the SM predict the existence of neutral, weakly coupled unstable particles with macroscopic decay lengths. Among these the Hidden Valley (HV) scenario predicts neutral long-lived particles, the so-called π_V, that decay to heavy quark pair and τ pairs. These particles can be produced in Higgs boson decays, supersimmetric processes and Z decays.

At the time of design, the ATLAS apparatus was not optimized to reveal neutral particles with long decay paths and di-jet final states displaced throughout the overall detector. As such these events, which might signal physics beyond the SM, would be undetected.

In collaboration with the INFN Rome1 group and the Seattle University, Washington, our group is involved in the study of the ATLAS detector performance for the Higgs decay into two π_V. The group is responsible of the search of the Higgs boson in the leptonic decay channel of the HV particle, in particular is active in the study of the acceptance of the existing as well as new ad-hoc designed triggers for this process. The leptonic decay channel represents the favorite decay mode for light Higgs boson and has a very clean topological signature. The group is also deeply involved in developing a realistic analysis strategy to reconstruct events from such unexplored physics.

3.3 HADRONIC CALORIMETRY

Physicists: L. La Rotonda
G. Crosetti
G. Susinno
T. Venturelli

Technicians: F. Pellegrino, V. Romano

International collaboration

High-precision measurements of hadrons and hadron jets have become increasingly important in experimental particle physics. The energy resolution of a hadron calorimeter is in general much worse than what can be achieved for e.m. shower detection. The wide variety of possible interaction processes and the effects associated with excitation of the absorber nuclei are considered responsible for this.

In compensating hadron calorimeters a dominant source of fluctuations that comes from π^0 production in the shower is eliminated by equalizing the calorimeter response to e.m. and purely hadronic shower component.

In recent years, R. Wigmans (Texas Tech) in collaboration with other groups have developed an alternative technique: The Dual Readout Method (DREAM). DREAM calorimeters are based on a simultaneous measurement of different types of signals which provide complementary information about details of the shower development.

The DREAM prototype, that has been successfully tested at CERN, is a copper absorber structure, equipped with two types of active media. Scintillating fibers measure the total energy deposited by the shower particles, while Quartz fibers measure the Cerenkov light that is only produced by the charged, relativistic shower particles.

Since the latter are almost exclusively found in the e.m. shower component (dominated by π^0 s produced in hadronic showers), a comparison of the two signals makes it possible to measure the energy fraction carried by this component, fem, event by event.

Once the effects of the dominant source of fluctuations, *i.e.,* fluctuations in the e.m. energy fraction fem, are eliminated, the performance characteristics are determined (and limited) by other types of fluctuations. In the described detector, a prominent role is played by the small number of Cerenkov photoelectrons constituting the signals (8 p.e./GeV) due to the small sampling fraction used in the prototype.

Moreover, for the measurement of electromagnetic showers and photons, it could be convenient to place in front to a DREAM-like calorimeter a high resolution electromagnetic homogenous calorimeter. In such a calorimeter it would be important to preserve the possibility of dual readout in order to correct the energy measurement of the fraction of hadrons developing electromagnetic showers already in this detector.

So, in order to improve the DREAM setup different ways are practicable:

a) Increase the sampling fraction in DREAM-like calorimeters, to increase the light collected

b) production of crystal electromagnetic calorimeters with dual readout to be placed in front of DREAM-like calorimeters, to improve the energy resolution of electromagnetic showers, keeping the possibility of measuring the electromagnetic fraction of hadrons showers that start in the electromagnetic calorimeter that can then be compensated on an event-by-event basis.

To this last project, with U.S. researchers an Italian collaboration: Bologna - Cagliari - Cosenza - Roma1 -Pavia is working from 2006.

In a homogeneous calorimeter the two light components can be disentangled by:

(1) Directionality. The Cerenkov light is emitted at a fixed angle with respect to the momentum vector of the particle that generates it, while the scintillation light is isotropically emitted.

(2) Time structure. The Cerenkov light is prompt, whereas scintillation processes have one or several characteristic decay times.

(3) The spectrum. The Cerenkov light is emitted with a characteristic λ^{-2} spectrum, while the scintillation processes have their own characteristic spectra.

(4) Polarization. Contrary to scintillation light, Cerenkov light is polarized

Very promising results have been obtained in case of single doped BGO crystals and a small electromagnetic calorimeter made of lead tungstate (PbWO4) crystals tested in conjunction with the DREAM calorimeter mentioned above, and exposed to high energy particle beams at CERN's Super Proton Synchrotron.

Time structure and spectrum of signals like to be the most interesting characterization of two signals.

The study of new crystals more efficient to discriminate scintillation and Cerenkov light and the development of a faster electronic are going on.

Respect to point a) theoretical studies are going on and the prototype construction will start in 2010.

The Cosenza Group participate to the Test Beam and data analysis and is responsible for the Geant simulation and for the on-line and off-line monitoring; it is involved in the studies relative to the new prototype and will contribute to the construction as soon as it will start.

3.4 3D PIXEL COLLABORATION

Physicists: M. Capua
S. Fazio
A. Mastroberardino
G. Susinno

Technicians: none

International collaboration

During 2009 our group actively contributed in data taking shifts, DQM and data analysis for the beam tests of the silicon 3D pixel detectors at CERN. The 3D pixel Collaboration was approved in July 2007 and includes 4 processing facilities: CNM Barcelona (Spain), FBK Trento (Italy) and the 3DC Consortium with SINTEF (Norway) and Stanford (USA). The main goals of these studies are the development, industrial fabrication, characterization and testing, with and without front-end readout chips, of full-3D with active-edge and mod (double side)-3D silicon pixel sensors of extreme radiation hardness and high speed for the the Super-LHC ATLAS upgrade and the ATLAS B-layer replacement (IBL).

A specific goal is to demonstrate the design implementations of 3D as a safe sensor solution for the IBL in the high radiation environment expected during the full period between the LHC phase-1 and phase-2 upgrades.

3.5 KLOE-2 EXPERIMENT AT DAFNE E-E+ COLLIDER (National Laboratory of Frascati)

Physicists: M. Schioppa
G. Morello

Technicians: none

International collaboration

The DAFNE collider accelerates and stores electrons and positrons of 510MeV energy each to produce PHI-mesons via the reaction e^+e^- -> gamma* -> PHI. This meson has 1020 MeV/c2 mass and the photon quantum numbers: $J^{PC} = 1^{--}$. It decays at rest mainly into charged and neutral kaon pairs, branching ratio BR=49.5% and BR=34.3% respectively, but also into RHO-PI and PI+PI-PI0 (BR=15.5%), ETA-GAMMA (BR=1.3%), ETA'-GAMMA (BR=0.00012). The neutral kaon pairs are produced in a well-defined quantum and kinematical state with negative

charge parity. The kaons are monochromatic (127MeV/c for charged kaons and 110MeV/c for the neutral one) and are emitted back to back to be detected in an almost background free environment. With the integrated luminosity of 2.5fb-1 (2001-2006) the collider has produced 10^10 PHI-mesons and than about 10^10 kaon pairs. For this reason the DAFNE collider is called a strangeness-producing factory.

DAPHNE has two interaction regions. The experiment KLOE is located in one of them. It is a general purpose detector designed to study all kinds of kaon, PHI, RHO, ETA and ETA' decays emphasizing tests of discrete symmetries (CP-, CPT-, T-invariance) and measurements of hadronic cross sections and tests of chiral perturbation theory.

The detector is a huge (4m diameter, 4m long), transparent drift chamber in 0.5Tesla magnetic field produced by a superconductive solenoid, with 55000 stereo wires, in helium based gas mixture, surrounded by a lead-scintillating fiber calorimeter, 15X0 thick, 98% solid angle coverage with a resolution of 54ps/SQRT(E)+140ps (E in GeV) in time and 5.7%/SQRT(E) in energy .

During 2008 the INFN has approved the KLOE-2 proposal at the improved DAFNE luminosity performance, of a two steps roll-in: winter 2009 up to the end of the year, to get the first flavour of the machine; may 2010 up to the end of the year to get the long data-tacking campaign (20-50fb-1).

The contribution to KLOE-2 project of the UNICAL's researchers has been focused on CCALT LYSO calorimeter performance studies by GEANT4 simulations, QCALT tile calorimeter tests with UV pulsed LED on photodiodes, tiles and fibers, cylindrical GEM inner tracker detector gas gain simulations, the absolute luminosity monitor calorimeter to measure the DAFNE luminosity during the 2008-2009 machine development and the study of light boson weekly coupled with standard matter named dark photon.

3.6 AIR SHOWER OBSERVATORY WITH SCINTILLATOR DETECTORS ARRAY

Physicists: M. Schioppa
Technicians: none

During the last 20 years the Astroparticle research has considerably contributed to the better understanding of the laws that govern the Universe but it has also leaved many open questions (i.e. the origin, the acceleration mechanism and the elementary composition of the Cosmic Rays) that can be coped only with ground based experimental apparatus that are the only capable to detect those CR coming from galactic and extragalactic exotic astrophysical sources and directly from the Big Bang. Indeed these particles have energy greater than 100TeV (UHE) and interact with the nuclei of the atmosphere generating extensive air showers (EASs). During the last years the ground-based apparatus have reached goals unattainable with the other techniques to explore the Universe. For example it has put in evidence a very large number of gamma-sources from our galaxy and from other galaxy, it has demonstrated the existence of very complex gamma sources, and it has discovered extragalactic gamma source at distance never explored previously.

The researchers of UNICAL physics department, with the precious collaboration of physics students, have designed and realized an EAS observatory made of 3 large scintillator counters placed at the vertex of a equilateral triangle, 20m side. The apparatus detects EAS produced by CR of energy greater than PeV and can measure the direction of the primary CR with a resolution of 5°. During 2009 the apparatus has collected about one million EAS and the data analysis is in progress. The apparatus is particularly suitable also for didactics purpose.

The UNICAL's researchers have presented a PRIN project for the realization of a ground-based apparatus to detect the muon content of the showers employing the last generation high precision drift chamber used in the colliding beam experiment like ATLAS. This apparatus can contribute to the determination of the energy of the primary Cosmic Ray, to the study of the elementary composition of the Cosmic Ray and the reconstruction of the muon tracks, allowing us to increase the angular resolution about the direction of the CR of at least one order of magnitude to respect the existing EAS-arrays.

A PUBLICATIONS ON SCIENTIFIC JOURNALS

A.1 Publications on international scientific journals

A.1.1 Publications on international scientific journals published on 2009

1. C. Milardi, M. Schioppa et al.,
Results from the Dafne high luminosity test,
Nuovo Cimento 32C (2009) 379-382.

2. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
Exclusive photoproduction of upsilon mesons at HERA,
Physics Letters B 680 (2009) 4-12.

3. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and H1-ZEUS Collaboration,
Multi leptons with High Transverse Momentum at HERA,
JHEP 0910 (2009) 13.

4. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
Multi lepton production at high transverse momentum at HERA,
Physics Letters B 680 (2009) 13-23.

5. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
Measurement of J/psi helicity distributions in inelastic photoproduction at HERA,
JHEP 0912 (2009) 007.

6. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
Scaled momentum distributions of charged particles in dijet photoproduction at HERA,
JHEP 0908 (2009) 077.

7. C. Milardi, M. Schioppa et al.,
Crab waist collision at DAFNE,
ICFA Beam Dyn. Newsletters 48 (2009) 23-33.

8. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
Measurement of the longitudinal Proton Structure Function at HERA,
Phys.Lett. B 682 (2009) 8:22.

9. C. Milardi, M. Schioppa et al.,
Present status of the DAFNE upgrade and prospective,
Int. Journal Modern Physics A 24 (2009) 360-368.

10. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
*Measurement of high Q**2 neutral current deep inelastic e-p scattering cross sections with a longitudinally polarized electron beam at HERA,*
European Physics Journal C62 (2009) 625-658.

11. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
Measurement of beauty photoproduction using decays into muons in dijet events at HERA,
JHEP 0904 (2009) 133.

12. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
Measurement of the charm fragmentation function in D photoproduction at HERA,*
JHEP 0904 (2009) 082.

13. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration,
Measurement of charged current deep inelastic scattering cross sections with a longitudinally polarized electron beam at HERA,
European Physics Journal C61 (2009) 223-235.

14. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Measurement of D+- and D0 production in deep inelastic scattering using a lifetime tag at HERA,* European Physics Journal C63 (2009) 171-188.

15. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *A measurement of the Q**2, W and t dependences of deeply virtual Compton scattering at HERA,* JHEP 0905 (2009) 108.

16. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Leading proton production in deep inelastic scattering at HERA,* JHEP 0906 (2009) 074.

17. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Deep inelastic scattering with leading protons or large rapidity gaps at HERA,* Nuclear Physics B 816 (2009) 1-61.

18. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Measurement of beauty production from dimuon events at HERA,* JHEP 0902 (2009) 032.

19. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Production of excited charm and charm-strange mesons at HERA,* European Physics Journal C60 (2009) 25-45.

20. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Search for events with an isolated lepton and missing transverse momentum and a measurement of W production at HERA,* Physics Letters B 672 (2009) 106-115.

21. L. La Rotonda and NOMAD Collaboration, *A measurement of coherent neutral pion production in neutrino neutral current interactions in NOMAD,* Physics Letters B 672 (2009) 177-184.

22. L. La Rotonda and NOMAD Collaboration, *A study of quasi-elastic muon neutrino and antineutrino scattering in the NOMAD experiment,* European Physics Journal C63 (2009) 355-381.

23. L. La Rotonda, E. Meoni, A. Policicchio, G. Susinno, T. Venturelli and DREAM Collaboration, *Dual readout calorimetry with crystal calorimeters,* Nuclear Instrument and Meth. A598 (2009) 710-721.

24. L. La Rotonda, E. Meoni, A. Policicchio, G. Susinno, T. Venturelli and DREAM Collaboration, *Neutron signals for dual readout calorimetry,* Nuclear Instrument and Meth. A598 (2009) 422-431.

25. L. La Rotonda, E. Meoni, A. Policicchio, G. Susinno, T. Venturelli and DREAM Collaboration, *New crystals for dual readout calorimetry,* Nuclear Instrument and Meth. A604 (2009) 512-526.

26. L. La Rotonda, E. Meoni, A. Policicchio, T. Venturelli and DREAM Collaboration, *Dual readout calorimetry with a full-size BGO electromagnetic section,* Nuclear Instrument and Meth. A610 (2009) 488-501.

27. C. Adorisio, D. Salvatore et al., *Study of the ATLAS MDT Spectrometer using high energy CERN combined test beam data,* Nuclear Instrument and Meth. A598 (2009) 400-415.

A.1.2 Publications on international journals accepted in 2009

28. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *A QCD analysis of ZEUS diffractive data* DESY-09-191, Nov 2009. 26pp. accepted by Nucl.Phys.B

29. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and H1 - ZEUS Collaboration *Combined Measurement and QCD Analysis of the Inclusive e+- p Scattering Cross Sections at HERA,* DESY-09-158, Oct 2009. 61pp. accepted by JHEP

30. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Events with an Isolated Lepton and Missing Transverse Momentum and Measurement of W Production at HERA.,* DESY-09-140, Nov 2009. 19pp. accepted by JHEP

31. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Measurement of J/psi photoproduction at large momentum transfer at HERA* DESY-09-137, Sep 2009. 38pp. accepted by Nucl. Phys. B

32. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Measurement of isolated photon production in deep inelastic ep scattering* DESY-09-142, Sep 2009. 23pp. accepted by Phys.Lett.B

33. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Measurement of dijet photoproduction for events with a leading neutron at HERA* DESY-09-139, Sep 2009. 40pp. accepted by Nucl.Phys.B

34. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Measurement of charm and beauty production in deep inelastic ep scattering from decays into muons at HERA* DESY-09-056, 2009. 36pp. accepted by Eur.Phys.J.C

35. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Measurement of charm and beauty production in deep inelastic ep scattering from decays into muons at HERA* DESY-09-056, 2009. 36pp. accepèted by Eur.Phys.J.C

36. M. Capua, S. Fazio, A. Mastroberardino, M. Schioppa, G. Susinno, E. Tassi and ZEUS Collaboration, *Scaled momentum spectra in deep inelastic scattering at Hera* DESY-09-229 (December 2009) accepted by JHEP

A.1.3 Public international notes in 2009

37. The ATLAS Collaboration, *Expected performance of the ATLAS Experiment – Detector, Trigger and Physics,* arXiv:0901.0512 (2009) 1-1852.

38. The ATLAS Collaboration, *Statistical combination of several important standard model Higgs boson search channels,* ATL-PHYS-PUB-2009-063, ATL-COM-PHYS-2009-222 (2009) 1-34.

39. The ATLAS Collaboration, *Search for the standard model H->ZZ*->4l,* ATL-PHYS-PUB-2009-054, ATL-COM-PHYS-2009-205 (2009) 1-28.

40. The ATLAS Collaboration, *Triggering on long-lived neutral particles in the ATLAS Detector,* ATL-PHYS-PUB-2009-082

B PUBLICATIONS ON CONFERENCE PROCEEDINGS

B.1 Publications on international conference proceedings in 2009

41. S. Fazio,
Exclusive Diffraction at HERA and Beyond.
Prepared for the Xth International School-Seminar: "The Actual Problems of Microworld Physics", Gomel, Belarus, July 15-26, 2009, arXiv:1001.3241.

42. M. Capua,
DVCS and high-t photons at HERA.
Prepared for the low-x 2009 Conference. Published in AIP Conf.Proc.1105:24-27,2009, 4pp

43. E. Tassi,
Recent results from the ZEUS experiment publication DIS2009
Proceeding for XVII International Workshop on Deep Inelastic Scattering and Related Subjects (DIS2009), 26-30 April 2009, Madrid, Spain

44. E. Tassi,
Combined HERA-I inclusive DIS cross sections
Proceeding for XVII International Workshop on Deep Inelastic Scattering and Related Subjects (DIS2009), 26-30 April 2009, Madrid, Spain

45. H. Gjersdal, E. Bolle, M. Borri, C. Da Via, O. Dorholt, S. Fazio, P. Grenier, S. Grinstein, P. Hansson, J. Hasi, F. Huegging, P. Jackson, C. Kenney, M. Kocian, A. La Rosa, A. Mastroberardino, P. Nordahl, F. Rivero, O. R hne, H. Sandaker, K. Sj b→ k, T. Slaviec, D. Su, J. Tsung, D. Tsybychev, N. Wermes, C. Young,
Tracking Efficiency and Charge Sharing of 3D Silicon Sensors at Different Angle in a 1.4 Tesla Magnetic Field
Prepared for HSTD7: the Seventh International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors, Hiroshima (Japan), August 29 - September 1, 2009. To be published on: HSTD7 Proceedings. Submitted to: Nucl. Instr. and Meth. A.

46. E. Bolle, M. Borri, M. Boscardin, G.-F. Dalla Betta, G. Darbo, C. Da Già, O. Dorholt, S. Fazio, C. Gemme, H. Gjersdal, P . Grenier, S. Grinstein, P. Hansson, J. Hasi, F. Huegging, P. Jackson, C. Kenney, M. Kocian, A. La Rosa, A. Mastroberardino, P. Nordahl, F. Rivero, O. Røhne L , H. Sandaker, K. Sjøbæk, T. Slaviec, D. Su, J. Tsung, D. Tsybychev, N. Wermes, and C. Young,
Radiation Hard 3D Pixel Sensors – Recent Results
Prepared for the Vertex 2009 - 18th Yearly Workshop on Vertex Detectors and Related Techniques - September 13-18, 2009 Veluwe (the Netherlands). To be published on: PoS: VERTEX 2009

47. A. La Rosa, M. Boscardin, G.-F. Dalla Betta, G. Darbo, C. Gemme, H. Pernegger, C. Piemonte, M. Povoli, S. Ronchin, A. Zoboli, N. Zorzi, E. Bolle, M. Borri, C. Da Via, S. Dong, S. Fazio, P. Grenier, S. Grinstein, H. Gjersdal, P. Hansson, F. Huegging, P. Jackson, M. Kocian, F. Rivero, O. Rohne, H. Sandaker, K. Sjobak, T. Slavicek, W. Tsung, D. Tsybychev, N. Wermes, and C. Young,
Preliminary results of 3D-DDTC pixel detectors for the ATLAS upgrade
Prepared for 9th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors – RD09, Florence, Italy. 30 Sep. - 2 Oct. 2009. e-Print: arXiv:0910.3788 [hep-ex]. Published on: PoS (RD09) 032, 2009

PRESENTATIONS AT SCHOOLS AND CONFERENCES

C.1 Invited presentations at international schools and conferences in 2009

48. M. Schioppa,
QCALT: a tile calorimeter for the KLOE-2 experiment.
11th ICATPP Conference on Astroparticle, Particle, Space Physics, Detectors and Medical Applications – Villa Olmo, Como 5-9 October 2009.

49. S. Fazio,
Exclusive Diffraction at HERA and Beyond.
Invited lecture at the Xth Internationale School-Seminar: The Actual Problems of Microworld Physics,

Gomel, Belarus, July 15-26, 2009.

50. M. Capua on behalf of the ZEUS Collaboration,
QCD analysis of diffractive data.
Talk at Low-x 2009, 8-13 September 2009, Ischia Island, Italy.

51. E. Tassi,
Overview of ZEUS results.
Plenary talk at XVII International Workshop on Deep Inelastic Scattering and Related Subjects (DIS2009), 26-30 April 2009, Madrid, Spain.

52. E. Tassi,
Combined data of inclusive DIS measurements at HERA I.
Talk at XVII International Workshop on Deep Inelastic Scattering and Related Subjects (DIS2009), 26-30 April 2009, Madrid, Spain.

4. SURFACE ELECTRON SPECTROSCOPY (SPES)

Professors and Researchers	Elio Colavita *(Group Leader)* Gennaro Chiarello Raffaele Giuseppe Agostino Vincenzo Formoso Tommaso Caruso
Postdoc fellows	Enrico Maccallini Alfonso Policicchio
PhD students	Antonio Marino Georgios Kalantzopoulos Myrsini Antoniou
Technicians	Salvatore Abate (Lycril/CNR) Giovanni Desiderio (Lycril/CNR) Vito Fabio Eugenio Li Preti
Collaborators	P. Milani *(University of Milano, Italy)* P. Rudolf *(Material Science Center, University of Groningen, The Netherlands)* C.E. Bottani (*Politecnico of Milan, Italy*) J. bNagy (*Dept of chemical and material engineering, Univ. of Calabria*) G. Golemme (*Dept of chemical and material engineering, Univ. of Calabria*) A. Goldoni *(Elettra, Trieste, Italy)* S. La Rosa *(Elettra, Trieste, Italy)* S. Scalese *(CNR, Catalina, Italy)* D. Gournis *(University of Ioannina, Greece)* F. Alamgir *(Brookhaven National Laboratory, New York, USA)* G. Froudakis (*University of Crete, Greece*) P. Trikalitis (*University of Crete, Greece*) F. Alamgir *(Georgia Institute of Technology, Atlanta, Georgia, USA)* G. Valenti *(University of Bari, Italy)* A. Politano (*Universidad Autonoma de Madrid, Cantoblanco. Spain)*

Introduction

Scientific basic research and applied physics have been carried out also during the last year. Vibrational studies have been performed in a number of research experiments: see for example: a) CO adsorption on clean and alkali-modified Ag single layers deposited on Ni(1111) and Cu(111) surfaces; b) Comparative vibrational study on alkali co-adsorption with CO and O on Ni(111) and Cu(111); c) Collective electronic excitations in as-deposited and modified Ag thin films grown on Cu(1111); d) Electronic properties of gold thin films studied by electro energy loss spectroscopy. The adsorption properties of different gases (H_2, CH_4 and CO_2) in MOF Cu-Btc type have been obtained by the PcT apparatus. The isotherm curves evidence a selective storage of the different gas species obtained by a Sievert-type apparatus up to 80 bar at 77K and room temperatures. The surface modifications, which are introduced in order to tune the permeance and selectivity of the sample to different gas molecules, do not produce any change in the sample morphological and structural properties. The SPES group has been involved in 2009 in collaborations with academic and industrial partnerships of the University of Ioannina and Crete (Greece), the Max Planck institute in Stuttgart (Germany), the Department of chemical and material engineering of the University of Calabria and the company INNOVA Technology Solutions (Italy). During those collaborations, the adsorption properties of porous nanostructured materials based on carbon and silicon at the equilibrium and dynamical conditions have been investigated at low and high pressure values by volumetric Sievert-type apparatus and the Pressure-concentration-Temperature (PcT) isotherms. In addition SEM and XRD measurements were also carried out on those samples by the equipments present in our Department, while the thermal desorption spectroscopy has been used in

some of them. The goal of this research is to use the engineering of the porous nanostructured materials in order to tune the adsorption properties of a possible storage medium or of a selector of different gas species inside a particular mixture. The tuning of the adsorption properties of porous nanostructured materials can be obtained by varying their 1) pore size distribution, 2) the interaction energy between the adsorbent (the material) and the adsorbate (gas species) by selected functionalization and 3) atomic constituent.
The going on collaboration with Prof. Giovanna Valenti of the University of Bari has the aim to integrate concepts and techniques from molecular cell biology, with high resolution microscopy (HRTEM) and structural biology by atomic force microscopy.

4.1 CHEMISORPTION ON METAL SURFACES

4.1.1 Chemical reactions at clean and alkali-doped mismatched metal/metal interfaces

High resolution electron energy loss spectroscopy has been used to study CO adsorption on clean and alkali-modified Ag single layers deposited on Ni(1111) and Cu(111) surfaces. An increasing of the CO dissociation rate was obtained for the alkali-doped Ag/Ni(111) interface. On the contrary, for a monolayer of Ag on Cu(111), alkali adsorption causes an increasing of the CO dissociation barrier. For higher Ag thickness (10 layers), the alkali-modified surface strongly reacts with water molecules.

4.1.2 Comparative vibrational study on alkali co-adsorption with CO and O on Ni(111) and Cu(111)

High resolution electron energy loss spectroscopy was used to investigate alkali (Na, K) coadsorption with CO and O on Cu(111) and Ni(111) . Measurements provided new insights in these systems. A CO-induced weakening of the alkali-substrate bond was revealed on both substrates. The effect is more pronounced for the Na+CO/Ni(1119 system, Submonolayers of alkalis werw found to promote the preferential population of the susurafce site for O/Cu(1119 but not for O/Ni(111).

4.2 ELECTRONIC PROPERTIES OF METALLIC FILMS

4.2.1 Probing Collective electronic excitations in as-deposited and modified Ag thin films grown on Cu(1111)

The nature and the dispersion of the electronic collective excitations in ultrathin Ag layers deposited onto the Cu(111) surface were investigated by angle-resolved high-resolution electron-energy-loss spectroscopy. For two Ag layers we found a nearly flat behavior of the surface-plasmon energy (absence of dispersion) as a function of the parallel momentum transfer. For higher coverages the surface plasmon is confined in Ag grains. The confinement of the surface plasmon was removed upon annealing. On the contrary, on the sputtered Ag film the quadratic term dominates.

4.2.2 Electronic properties of gold thin films studied by electro energy loss spectroscopy

High resolution electron energy loss spectroscopy was used to investigate the electronic properties of (111) oriented Au ultrathin films grown on Cu(111). The loss spectrum showed several features which were ascribed to both single and collective excitations. In particular we distinguished features assignable to disperionless single-particle transition and the dispersing electro-hole continuum as well as the ordinary s-like surface plasmon and the multipole surface plasmon.

4.2.3 Electronic properties of metallic bilayers deposited on Cu(111)

The nature and the dispersion of the electronic collective excitations in different metal bilayers (Na, Ca, Ag) deposited onto the Cu(111) surface were investigated by angle-resolved electron energy loss spectroscopy. We found a nearly-flat behavior of the surface plasmon energy (absence of dispersion) in Ca and Ag bilayers, characterized by the presence of d electrons, in good agreement with theoretical predictions within the framework of the s–d polarization model. On the contrary, an initial negative dispersion was observed in the Na bilayer. The intensity of the surface plasmon was vanishing in the long-wavelength limit in all cases.

4.2.4 Damping of the surface plasmon in clean and K-modified Ag thin films

The damping processes of electronic collective excitations of Ag/Ni(1 1 1) were studied by high-resolution electron energy spectroscopy. The FMHM of the Ag surface plasmon was reported as a function of Ag thickness, primary electron beam energy, Ag surface plasmon energy, and parallel momentum transfer. The broadening of the Ag surface plasmon was found to be related to 5sp ‼ 5sp transitions, for which a critical wave vector of 0.2 A-1 exists. Moreover, we provide a direct evidence of the occurrence of chemical interface damping in thin films, upon doping the Ag/Ni(1 1 1) system with K adatoms. The enhanced plasmon broadening in K/Ag/Ni(1 1 1) was ascribed to the existence of additional electron hole decay channels at the K/Ag interface.

4.2.5 Annealing effects on the plasmonic excitations of metal/metal interfaces

The effects of the annealing procedure at 400-450 K on the electronic properties of nanoscale thin films of Ca, Au and Ag grown on Cu(111) at room temperature were probed by high resolution electron energy loss spectroscopy measurements. Ca surface plasmon underwent to a significant red shift upon annealing due to the oxidation of the topmost Ca layer. Water strongly interacted with the CaO interface at room temperature. Au surface plasmon disappeared upon annealing the gold film, as a consequence of the formation of an Au-Cu alloy. Ag surface plasmon red shifted both in the annealed adlayer and with increasing temperature compared with the frequency recorded for the as deposited silver film.

4.3 SPECTROSCOPIC AND MICROSCOPIC STUDIES OF CARBON/METAL-OXIDE NANOSTRUCURE

4.3.1 Photoemission and microscopic investigation on WO3 thin films

Tungsten trioxide thin films were deposited (prof. E. Cazzanelli, Raman Laboratory, Physics Department - UNICAL) by spin coating on ITO/glass substrates and have been studied by X-ray and Ultraviolet Photoelectron Spectroscopy (XPS-UPS), and by Scanning Electron Microscopy – Energy Dispersive X-ray (SEM-EDX) analysis. The analyses were also accomplished by synchrotron radiation techniques (spatially resolved UPS) at the Elettra synchrotron light source in Trieste. The structural and compositional transformations of the WO3 films and/or of the ITO/glass substrates were followed after different thermal treatments in the range between 100°C to 700°C. XPS and UPS analysis showed the segregation of sodium elements from the glass substrates on the film surface after the 700°C thermal treatment, concomitantly to a structural reorganization of the WO3/ITO and ITO films. The SEM investigations probed the morphology of the samples showing the formation of a WO3 film organization on micrometric scale after 700°C thermal treatment in air. Investigation of the ITO/glass substrates revealed instead the growth of micrometric islands on top of a flat substrate following the same thermal treatment. EDAX analysis shows that these islands, on average, are richer in some glass-forming elements, namely Na, Mg, Ca and Al, with respect to Si. Moreover an interesting anomalous enhancement of the WO_3 films Raman signal was measured (Raman Laboratory) on top of some of the islands formed on the ITO-covered glasses substrates subjected to this proper thermal annealing.

4.3.2 Microscopic characterization on carbon/metal nanocomposites

We performed the characterization of nanostructured carbon/metal composites deposited by Supersonic Cluster Beam (collaboration with prof. P. Milani). The films were deposited with different thickness and metal doping. The microscopic studies were performed by scanning electron microscopy (SEM), the morphology of the films was strictly related to the film thickness with smooth surfaces for 30nm thickness and higher roughness at a 200nm one. The SEM microscope was also used in environmental mode (in-situ pressure up to 20 mbar) to study the condensation of water droplets from the vapor phase and show the morphology influence on the condensation behaviour. The wetting of the carbon films was also accomplished by the sessile drop method showing an increased wetting for higher roughness.

Thermal effect treatment were also studied and after a 250°C thermal treatment in air the most porous films showed a complete wetting behaviour. These studies were the core or the national project PRIN "*Novel approach to growth and characterization of carbon-based nanostructured and nanocomposite materials with extended interface*" funded by the MIUR in collaboration with prof. P. Milani of the University of Milano.

4.3.3 Nanostructured titanium oxide films with tailored physical and chemical properties reactivity

Titanium dioxide is widely employed in photocatalysis, electronics and biotechnology. Many TiO_2 properties strongly depend on its nanostructure; hence, for the production of technological devices, it is crucial to develop nanoscale control of the morphology and structure of the material as well as of its surface properties (wettability). This goal can be achieved by Pulsed Laser Deposition (PLD) and recently our group started a collaboration with the NanoLab group in Politecnico di Milano, Italy focused on the electronic and chemical characterization of PLD TiO2 systems. The TiO2 nanostructured films were synthesize by PLD in background gases (O2/Ar mixtures) at different pressures (10-60Pa) and in order to tailor their overall structural properties and physico-chemical properties of the thin films have been studied by photoelectron and x-ray absorption spectroscopy (XPS, UPS and XAS) in our laboratory and at the Material Science beamline (ELETTRA synchrotron radiation source, Trieste, Italy) in order to unveil the interplay between electronic and structural properties at the nano scale. Accordingly to the growth parameters the samples show different morphologies ranging from compact (10 Pa Ar/O2 background pressure) to porous structures (60 Pa Ar/O2). Photoelectron from Ti 2p core levels showed the component typical of TiO2 stoichiometry. However valence band spectra show the growth of a defect state after an high flux beam irradiation. The intensity of the defect feature depends however on the samples structure. Concomitant analysis of O and C levels showed the presence of Ti-bonded hydroxyl groups with increasing trend versus deposition pressures. The local order was investigated by XAS and Raman spectroscopy. The samples have mixed amorphous-crystalline structure but ordering is clearly higher at

lower synthesis pressure. Annealing in air (up to 673 K) induces anatase phase transition and a higher density of hydroxyls groups on the surface. These studies have shown how PLD can tailor in a viable way the sample different properties: morphological (compact to nanoporous structures), chemical (quantities of hydroxils bonded groups, stability under irradiation), electronic-structural (proper mixing of rutile, amorphous and anatase phase) depending on the growth parameters and thermal treatment. Moreover the controlled presence of OH radicals attached to defects sites can explain the instability of the samples under beam irradiation and may be important in the photochemical response of the sample.

4.4 MORPHOLOGICAL AND STRUCTURAL CHARACTERIZATION AND VOLUMETRIC GAS ADSORPTION EVALUATION OF MESO AND MICROPOROUS MATERIALS WITH HIGH SURFACE SPECIFIC AREA

4.4.1 New graphitic and silicalite nanostructured materials utilized for H2 and CH4 storage respectively

Graphitic samples with tuneable interlayer distances have been synthesized starting from graphite oxide material in collaboration with the University of Ioannina, in order to obtain porous materials for H2 storage application. The samples presented thermal and mechanical stability, even at high hydrogen pressure and presented high wt% of stored hydrogen even after several cycles of measurements. The samples present a strong and weak amounts of adsorbed hydrogen and in order to release the quantities strongly bonded, the samples need reactivation by thermal heating at 200°C for few hours. In addition extensive investigation of the adsorption properties of periodically nanostructures organo-silane samples with CH4 has been obtained showing particular dependence of the maximum storage capacity on the pore size of the samples.

4.4.2 Metal organig framework for gas (H2, CH4 and CO2) storage and selectivity/purification

The adsorption properties of different gases (H_2, CH_4 and CO_2) in MOF Cu-Btc type have been obtained by PcT apparatus. The isotherm curves evidence a selective storage of the different gas species. In particular, at room temperature, the CO2 present the highest storage capacity compared to the CH4 and H2, due to the higher polarity of the molecule which enhances the interaction between the adsorbent and the adsorbate. This enhanced interaction is also reflected in the kinetic properties of the gas species which result in a slower diffusion of the CO2 molecules also due to the the higher dynamical radius of CO2 molecules.

4.4.3 Silicon-based nanostructured materials for gas (H2, CH4 and CO2) storage and selectivity/purification

The adsorption properties of different gases (H_2, CH_4 and CO_2) in organo-silane surface-modified silicalite-1 (MFI), and in SAPO-34 (CHA, silicoaluminophosphate) have been obtained by a Sievert-type apparatus up to 80 bar at 77K and room temperatures. The surface modifications, which are introduced in order to tune the permeance and selectivity of the sample to different gas molecules, do not produce any change in the sample morphological and structural properties. Careful analysis of PcT isotherms with selected models can give information on the dynamical and equilibrium behaviors of H_2 molecules. In particular the fitting results of PcT isotherms by Toth models indicate the heterogeneity/homogeneity of the samples adsorption properties. In the hydrogen adsorption investigation those properties change depending on the pressure range. However the maximum storage capacity obtained at 8 MPa and 77 K on the different modified silicalite-1 is similar because the modification is external to the samples. On the other hand the diffusion time of hydrogen molecules into the samples is different depending on the pressure range and the sample surface modification. In our case higher heterogeneity of the samples adsorption properties corresponds to higher diffusion time. Therefore the modification introduces variations on the dynamical properties of the samples. The same analysis has been obtained on the CH_4 and CO_2 adsorption properties showing, in the SAPO-34 sample, higher storage capacity and slower gas diffusion compared to the hydrogen adsorption which could result in significant changes in the gas permeance. The unchanged hydrogen adsorption/desorption properties of the modified and unmodified samples are confirmed from TDS spectra except for strongly H_2 molecules bound to the external silanol group of unmodified silicalite-1. That active sites is not present in modified silicalite-1 because of the silanol group are saturated from the oragno-silane molecules. The kinetic parameters analysis by PcT apparatus is corroborated from the TDS spectra analysis acquired at different desorption rate which present thermal shifts which are attributed to mainly surface diffusion of desorbed hydrogen molecules.

4.4.4 Production and characterization of high surface area activated carbon for gas storage/separation applications starting from cellulose microcrystalline

High surface area carbonaceous materials properties are really interesting for applications like gas adsorption and separation. In the last year our group worked on production and characterization of activated carbon pellet without a binder from cellulose microcrystals as a raw material. We investigated different possible procedure to get the best sample in terms of specific surface area (SSA), density and porosity of the materials itself. We carried out SEM and XRD measurements for the structural and chemical characterization. Moreover, in collaboration with the Department

of chemical and material engineering of the University of Calabria we performed BET measurements to evaluate the SSA. Next step is the adsorption properties characterization of different gases (H_2, CH_4 and CO_2) in our sample. Investigation at low and high pressure will be evaluated by volumetric Sievert-type apparatus and the Pressure-concentration-Temperature (PcT) isotherms. The goal of this research is to synthetization and the engineerization of the high surface area activade carbon (nanostructured material) in order to tune the adsorption properties toward the DOE target as either storage medium either selector of different gas species.

4.5 SELECTIVE TRANSPORT ACROSS BIOLOGICAL MEMBRANES

4.5.1 Electron microscopy studies of biological mebranes

Proteins called Aquaporins specifically transport water across biological membranes with high velocity and specificity. Clarifying the structural basis of this remarkable property is one of the main areas of aquaporin research. Electron crystallography at a 3.8 Å resolution showed the structure of AQP1 and gave first insight into water specificity and proton blockage. AQP0 structure is determined to a resolution of 1.9 Å. These studies confirm the structural basis for the mechanism of high speed water permeation without transfer of protons. The physiological roles of aquaporins are known to different degrees of detail. Aquaporins are potential targets for drugs. For instance, blockers of kidney aquaporins will function as diuretics. Specific aquaporin blockers are presently not available. A complete understanding of the mechanisms of transport, substrate specificity and regulation will require the atomic structures of all human AQPs. This project is carried out in collaboration with Prof. Giovanna Valenti of the University of Bari and its success requires innovative integration of concepts and techniques from molecular cell biology; high resolution microscopy (HRTEM), structural biology by atomic force microscopy, computational biology via molecular dynamics simulation and mathematical modelling. Since AQP2 channel fusion to the plasma membrane is expected to modify cell surface architecture, the analysis of those morphological modification by scanning electron microscopes (SEM) is under investigation.

The collaboration between Prof. Giovanna Valenti, well known scientist for the leading research in the cell Physiology of Aquaporirns and the SPES group, expert in microscopic techniques at high resolution, is focused on ambitious scientific goals:

- Achieve a detailed understanding of the structural determinants and modifications of Aquaporins in living cells
- Achieve an understanding of the physiological role of aquaporins in order to assess their importance in health and disease and their use as drug targets.
- Fully understand the structural determinants of transport, specificity and regulation of aquaporins to support rationale drug design and to elucidate the mechanisms of action of novel aquaporin blockers.

International and National Projects

a) Proposal full title: **An innovative approach to the growth and characterization of carbon based materials with extended interface**
Italian PRIN National project
Name of the coordinating person: Prof. Paolo Milani
List of participants:

1 (Coordinator) Università di Milano
2 Physics Dept, Università della Calabria
Period: 2006 - 2008

b) Proposal Full Title: **Novel routes to pillared graphene**
EU Type of funding scheme: Collaborative project
Call: FP7-NMP-2009-SMALL-3

Topic: NMP-2009-2.1-1 Nano-structured materials based on graphene
Name of the coordinating person: George Froudakis
List of participants
1 (coordinator) University of Crete Greece Academic
2 Università della Calabria Italy Academic
3 University of Ioannina Greece Academic
4 Rijksuniversiteit Groningen The Netherlands Academic
5 University of Trieste Italy Academic
6 SCATEC AS Norway SME
Application on 16/02/2009

c) Proposal full title: **Enhanced Multifunctionalities in Photoactive Materials Achieved by Synergetic Scaffolding**
EU Collaborative Project: FP7-NMP-2009-SMALL-3
Work programme topics addressed: NMP-2009-1.2-2 Molecular factory: manufacturing objects with predictable and controllable properties

Name of the coordinating person: Prof. Mauro Ghedini
List of participants:
1 (Coordinator) Università della Calabria ITALY High Education Institution/ University
2 NANOPART BELGIUM SME end-user
3 SOLIS S.p.A. ITALY SME end-user
4 Université de Rennes FRANCE High Education Institution/ University
5 Instituto de Ciencia de Materiales de Madrid SPAIN National Research Council
6 Universitatea din Bucaresti ROMANIA High Education Institution/ University
Application on 16/02/2009

d) Proposal full title: **Electrocatalysts for polymer electrolyte membrane fuel cells: synthesis, characterization, spectroscopic studies of conventional and innovative catalysts and tests from -10 to 120°c.**
Italian PRIN National project
Name of the coordinating person: Prof. Gennaro Chiarello
List of participants:
1 (Coordinator) Physics Dept, Università della Calabria
2 Politecnico di Torino
3 ITAE/CNR Messina
Application on 26/02/2009

e) Proposal full title: **Hybrid polymer-inorganic nanostructured membranes for the separation of hydrogen and helium from gas mixtures**
Italian PRIN National project
Name of the coordinating person: Dr. Giovanni Golemme
List of participants:
1 (Coordinator) Chemical And Materials Engineering Dept, Università della Calabria
2 Physics Dept, Università della Calabria
Application on 26/02/2009

f) Proposal full title: **COmplex and NOvel Supported Clusters on surfaces and Oxide layers: a twofold approach towards bridging the gap between model and real catalysis studies.**
Italian FIRB - PROGRAMMA "FUTURO IN RICERCA" project
Name of the coordinating person: Dr. Tommaso Caruso
List of participants:
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2 Politecnico di Milano

3 Università di Milano
Application on 26/02/2009

g) Proposal full title: **Composite membranes with controlled transport properties for separation processes**
Italian FIRB - PROGRAMMA "FUTURO IN RICERCA" project
Name of the coordinating person: Dr. Maria Grazia De Angelis
List of participants:
1 (Coordinator) Università di Bologna
2 Physics Dept, Università della Calabria
3 ITM/CNR Rende (CS)
Application on 26/02/2009

h) Proposal full title: **Oxide Meso and Nanostructured Surfaces for Innovative light HArvesting**
Italian FIRB - PROGRAMMA "FUTURO IN RICERCA" project

Name of the coordinating person: Dr. Andrea Li Bassi
List of participants:
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2 Physics Dept, Università della Calabria
Application on 26/02/2009

A PUBLICATIONS ON SCIENTIFIC JOURNALS

A.1 Publications on international journals

A.1.1 Publications on international journals printed in 2009

1. Politano A., Agostino R.G., Colavita E., Formoso V., Chiarello G.,
Collective excitations in nanoscale thin alkali films: Na/Cu(111),
Journal of Nanoscience and Nanotechnology, NuovaSerie, 2009, Vol. 9, pp. 3932-3937.

2. Politano A., Formoso V., Colavita E., Chiarello G.,
Probing collective electronic excitations in as-deposited and modified Ag thin films grown on Cu(111),
Physical Review B, 2009, pp. 045426-1-045426-7.

3. Politano A., Chiarello G.,
Electronic properties of gold thin films studied by electron energy loss spectroscopy,
Gold Bulletin, 2009, Vol. 42, pp. 195-200.

4. Politano A., Formoso V., Chiarello G.,
Electronic properties of metallic bilayers grown on Cu(111): a comparative study,
Surface Science, 2009, Vol. 603, pp. 933-937.

5. Politano A., Formoso V., Chiarello G.,
Comparative vibrational study on alkali coadsorption with CO and O,
Journal of Physics: Condensed matter, 2009, Vol. 21, pp. 264006-1-264006-7.

6. Politano A., Formoso V., Chiarello G.,
Damping of the surface plasmon in clean and K-modified Ag thin films,
Journal of electron spectroscopy and related phenomena, 2009, Vol. 173, pp. 12-17.

7. Politano A., Chiarello G.,
Collective electronic excitations in systems exhibiting quantum well states,
Surface Review and Letters, 2009, Vol. 16, pp. 171-190.

8. Politano A., Formoso V., Chiarello G.,
Chemical reactions at clean and alkali-doped mismatched metal/metal interfaces,
The Journal of Physical Chemistry C, 2009, Vol. 113, pp. 316-320.

9. Politano A., Formoso V., Chiarello G.,
Annealing effects on the plasmonic excitations of metal/metal interfaces,
Applied Surface Science, 2009, Vol. 255, pp. 6038-6042.

10. Politano A., Chiarello G.,
Tuning the lifetime of the surface plasmon upon sputtering,
Physica status solidi RRL - Rapid Research Letters, 2009, Vol. 3, n. 5, pp. 136-138.

11. Politano A., Formoso V., Chiarello G.,
Interference effects in the excitation of collective electronic modes in nanoscale thin Ag films,
Superlattices and Microstructures, Nuova Serie, 2009, Vol. 46, pp. 166-170.

12. Politano A., Formoso V., Chiarello G.,
Dispersion and damping of surface plasmon in Ag thin films grown on Cu(111) and Ni(111),
Superlattices and Microstructures, Nuova Serie, 2009, Vol. 46, pp. 137-140.

13. Politano A., Formoso V., Chiarello G.,
Effects of O adsorption on the Na+CO/Ni(111) system,
Superlattices and Microstructures, Nuova Serie, 2009, Vol. 46, pp. 10-13.

14. Castriota M., Caruso T., Policicchio A., La Rosa S., Agostino R. G., Cazzanelli E.,
Anomalous enhancement of Raman scattering of metal oxide film deposited on thermally treated ITO-coated glass substrates,
Chemical Physics Letters, 2009, Vol. 478, pp. 195-199.

5. CONDENSED MATTER PHYSICS

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The research activity of the group is oriented in seven closely related directions, which are briefly described in the following sections:

5.1 Surface Nanoscience
5.2 Secondary Electron emission and charge transfer processes in the interaction of slow ions and electrons with solids
5.3 Photon-matter interaction: electronic properties of graphene and related materials
5.4 Quantum coherence and correlations in condensed matter systems
5.5 Ion interaction with nanostructures and solids
5.6 Multimedial education
5.7 Cultural Heritage

5.1 SURFACE NANOSCIENCE

5.1.1 Electronic and vibrational properties of carbon based nanostructures interacting with metal and gases.

Our scientific activity is based on the fields of surface science, particularly on surfaces studies of transition metals, chemisorption, synthesis and characterization of new materials; in recent years particular efforts have been devoted to the study of low dimensional carbon based nanostructures performing several experimental investigations on carbon nanotubes and graphitic layers. The importance of nanotechnology, with its intimate relation to electronics and its developing connections to bio-technology, is known to everybody. The study of low-dimensional electron systems has a long history and an immense intrinsic scientific interest but on the practical side, it is equally true that, such fields as nanophysics and nanotechnology are basically limited to the creation of truly low-dimensional nanoengineered materials. The building block material for all nanographitic forms is a flat monolayer of carbon atoms tightly packed into a two-dimensional (2D) honeycomb lattice, graphene, which has been studied theoretically for about sixty years [P. R. Wallace, Phys. Rev, 71 622 (1947)]. It is at the basis of the modeling of the electronic structure of carbon-based systems of all dimensionalities: it can be wrapped up into 0D fullerenes, rolled into 1D nanotubes or stacked into 3D graphite.

Regarding to this topic, our major achievement was the understanding of the variation of the electronic and chemical properties of bundles of Single Wall Carbon Nanotubes (SWCNTs) by insertion of electron donor species, such as alkali metal atom or nitrogen. Moreover, the extreme sensitivity of both electronic and transport properties of Carbon Nanotubes (CNTs) upon gas exposure, together with their peculiar structure offering large surface areas, make the study of gas adsorption on CNTs an attractive topic for gas sensing applications.

More recently we have investigated the effects of oxygen exposure on lithium-intercalated single wall carbon nanotube bundles at room temperature, and the evolution of surface configuration versus temperature. X-ray and Ultraviolet photoelectron spectroscopy measurements show a remarkable increase of surface lithium concentration, associated to modifications suffered by both core-level O 1s line shape and valence band spectra. These results have been attributed to the occurrence of lithium surface segregation induced by interaction with oxygen species. The enhanced sample reactivity caused by the alkali presence, allows the adsorption of oxygen, which in turn induces lithium atoms segregation from the bulk. This process results in a strong increase of the lithium surface concentration, and is followed by the formation of both lithium oxide and peroxide.

A temperature-dependent study has shown that lithium peroxide decomposes at 400K causing the increase of lithium oxide concentration, which has a more stable bond; at temperatures higher than 900K both oxygen and lithium desorb, and the electronic structure of the pristine sample is recovered.

Standard facilities for surface characterization, such as High Resolution Electron Energy Loss (HREELS), Low Energy Electron Diffraction (LEED), X-ray Photoelectron Spectroscopy (XPS), Ultra-violet Photoelectron Spectroscopy (UPS), and Auger Electron Spectroscopy (AES), were used in the above mentioned studies. This suggests that the same apparatus and techniques are suitable for investigating the electronic and vibrational properties of most nanomaterials interacting with metal and gases.

Currently our team is involved in the epitaxial growth of a monolayer graphite (MG) by chemical vapour deposition of hydrocarbons on metal surfaces, which represents the most promising alternative route to grow graphene sheets. Atomic epitaxial growth of graphene by chemical vapour deposition of hydrocarbons on metal surfaces was widely studied by surface science techniques [A. Nagashima et al., Surf. Sci. 291, 93 (1993)]. It has been recognized that "monolayer graphite" (MG), which means graphite overlayer with a thickness of one atomic layer, is successfully grown on some solid surfaces. Various properties of this system have been studied by photoelectron spectroscopies (XPS, UPS), and high resolution (HR) electron energy loss spectroscopy (EELS). Because of large anisotropic chemical bonding of the graphite, the electronic states of MG on solid substrates have a stronger localization at the overlayer plane than other atomic overlayers reported in the literature. For this reason, MG may be considered to have typical 2D electronic states confined in one atomic-layer thickness and has the potential of providing a testing field for the physical world at a reduced scale. In particular, 2D plasmons, whose charge fluctuations are strongly localized at a monolayer,

have been discussed theoretically for a long time [F. Stern,Phys. Rev. Lett. 18, 546 (1967), D.M. Newns, Phys. Lett. 38A, 341 (1972), C.C. Grimes et al., Phys. Rev. Lett. 36, 145 (1976)], although only a few experimental data have been reported so far [S. J . Jr Allen et al. Phys. Rev. Lett. 38, 80 (1977), A. Nagashima et al. Solid State Comm. 83, 581 (1992)] because it was difficult to prepare an excellent 2D sample with a large number of confined electrons.

One of the aims of our current experimental work is to bridge this gap with a detailed EELS study of weakly bonded MG.

We are growing graphene layers by cracking under vacuum ethylene at high temperature on Ni(111) single crystal surfaces. The process is automatically stopped when the substrate is covered completely with a graphite overlayer with the thickness of one atomic-layer. This is related to the fact that the surface reactivity of the substrate is extraordinary reduced by the graphite overlayer.

The electronic properties and consequently the anomalous behavior of electrons in graphene are expected to be very sensitive to the presence of substrate.

Actually, angle resolved EELS is capable of detecting the detailed plasmon dispersion, but such a study is so far missing for free-standing isolated sp2 carbon materials. Thus, the fundamental properties of ultra-thin films graphite can be discussed on the basis of the data, on dispersion relations of valence electrons, phonon dispersion and collective excitations, acquired with Angle Resolved Electron Spectroscopy (EELS and UPS mainly). The interfacial orbital mixing of the π states of the overlayer with the d states of the reactive substrates is the origin for the phonon softening, modification of the π band and two-dimensional plasmons with high electron density.

Understanding the interaction of epitaxial graphene layers with the metallic substrate is an important step from both fundamental and technological point of view. The influence of the substrate, indeed, induces a change in the charge distribution and consequently in the electronic properties of the overlayer in comparison with a free standing graphene sheet or with a 3D graphite stack.

5.1.2 Secondary electron emission from graphene on metal surfaces

Secondary electron emission, induced by slow ions and electrons incident on solids, is a phenomenon that reveals high sensitivity to the surface properties of the target materials, as demonstrated by a number of spectroscopic techniques and applications, such as scanning electron microscopy. It is therefore quite surprising that the spectroscopy of low energy electrons emitted from graphene has not yet been tested for fundamental studies and possible technological applications.

We report on kinetic energy distributions of electrons emitted during bombardment of MG by 2-4 keV singly charged Helium ions and 0.15-1.6 keV electrons. The use of He+ projectiles is motivated by the interest in the fundamental physics of ion-surface interactions, where several electron excitation mechanisms are not yet well understood. Indeed, collective excitations and quasiparticles, produced by low energy ions incident on solids, have been investigated only recently, such as plasmons and shake up electrons in metals, as well as excitons in insulators and highly oriented pyrolytic graphite (HOPG). Therefore, we expect the energy distribution of electrons, emitted by the impact of 2-4keV He+ ion on graphene, to be a good testing ground for the study of excitonic effects studied in slow ion-HOPG collisions. Structures observed in the spectra of electrons, excited by the impact of Helium ions, are interpreted in terms of the autoionizing decay of electronic transitions governed by the electron-hole interaction, similarly to the case of optical excitations induced by photon or electron absorption. The proposed emission mechanism should be effective also on other materials such as wide gap insulators and might explain features observed in electron emission spectra of Lithium Fluoride.

Another issue addressed in our experiments is related to possible future applications of graphene adsorbed on metal surfaces. Measurements performed with 0.15-1.6 keV electron beams show the low electron emission yield of graphene on Ni(111), which feature, not yet understood, is typical of graphitic materials. This result suggests the use of MG in applications where a low and stable electron emission yield is required, due to the inertness of the graphene layer. Measurements of energy distributions of electrons emitted by electron impact reveal a low electron emission yield and suggest graphene as a possible advantageous coating material in applications where this property is required. The nanometric thickness of the sample indicates that the low emission yield of graphitic materials is related to their anisotropy, rather than to the in-depth penetration of the excitation cascade.

5.2 SECONDARY ELECTRON EMISSION IN THE INTERACTION OF SLOW IONS AND ELECTRONS WITH SOLIDS

5.2.1 Electron Emission Spectra from Clean and Cesiated Al Surfaces

Secondary electrons (SE) are those electrons of a target material that are emitted in vacuum by the impact of energetic (primary) particles. The phenomenon is the basis for several spectroscopic techniques for surface analysis and characterization of materials, as well as for the scanning electron microscope. Secondary electron emission play

also a crucial role in a wide variety of areas, including electron multipliers, electrical discharge and plasma processing of materials, particle accelerators and plasma-wall interactions in fusion reactors. Electron emission may be a problem that needs to be avoided or reduced, such as electron cloud effects in high-energy accelerators and storage rings. Progress in all these areas call for advances in the basic understanding of electron emission in particle-solid interactions. This motivates the study of the energy distribution of emitted electrons $N(E)$ and of its integral, the electron emission yield δ, as a function of several variables, such as impact energy, incidence and emission angles, as well as surface conditions.

Electrons excited by the projectile inside the solid undergo multiple collisions with other electrons in the solid. Electron emission occurs when this collision cascade is interrupted by the surface and the excited electrons have energies above the vacuum level. When the primary particles are electrons, the part of $N(E)$ due to secondary electrons overlaps with that of primary electrons that have been reflected from the solid. In this case, N(E) contains a sharp peak due to primary electrons elastically reflected (*elastic peak*) and nearby structure on the low energy side due to energy losses of reflected primary electrons (also termed *rediffused*). Sharp peaks in that structure contain electrons that lost energy in excitation of a discrete number of surface and volume plasmons. Evidence of plasmon excitation also appears in the low-energy part of $N(E)$ of some solids as a structure containing electrons across the valence band than can be excited by plasmon decay above the vacuum level. The plasmon decay structure is often difficult to visualize because it is superimposed on the low energy part of the collision cascade. This factor hinders the, yet unanswered, question of the quantitative contribution of plasmon decay to the total secondary electron emission

We investigated the role of plasmon decay in secondary electron emission through measurements of energy spectra of electrons emitted by 130 eV and 2 keV electron impact on clean and cesiated Al surfaces. Electron emission from the clean metal surface appears to be dominated by plasmon decay features. The electron collision cascade excited by plasmon decay appears not to be as important as considered in theoretical calculations. Modification of the surface by adsorption of Cs shows that the main channel for plasmon excitation is indirect, by fast secondary electrons travelling inside the solid.

The data allow also to discuss an issue that is important in many phenomena and applications, where electron emission is a relevant process. Many of these phenomena are studied by means of simulation codes that show a strong sensitivity to parameters pertaining the electron emission yield δ and the energy distribution of emitted electrons *N(E)*. The reliability of electron yields extracted from experimental energy spectra is therefore an important requirement. Our data allow to illustrate a very simple data analysis procedure to accomplish this requirement, particularly for those application where electron reflection is important. The analysis of electron energy distributions measured as a function of surface modification allowed us to separate the spectrum of rediffused electrons from the continuum background of cascade electrons. The results show that values of yields of rediffused electrons currently used in several applications may be significantly overestimated. More generally, our work shows that the interplay between different emission mechanisms in many cases cannot be neglected, as electrons of different origin can have the same characteristic energy. This implies that application of data analysis techniques to experimental spectra is required whenever there is the need to disentangle different contribution to the electron emission yield. Furthermore, the separation may be important because the behavior of the two components of the spectrum might change with surface conditions, as in the experiments reported here, as well as with impact energy, incidence and emission angles.

5.2.2 Kinetic Electron Emission from Metal Surfaces by slow Na^+ ions

Kinetic electron emission (KEE) during the interaction of slow atomic particles with metal surfaces, i.e., the emission of electrons at the expense of the kinetic energy of incoming projectiles, has been intensely investigated but, despite a considerable effort, the microscopic mechanism of KEE has not been identified in most cases, particularly not at very low impact energies. At higher impact energies, basic mechanisms of KEE from metal surfaces are excitations of solid valence electrons in binary projectile-electron collisions in an idealized Fermi electron gas, and electron promotion in close atomic collisions. Both these processes are subject to a threshold impact velocity or energy below which their contribution to the emission decreases rapidly. Nevertheless, even below the thresholds, the magnitude of the observed KEE is usually quite strong .

Electron emission from metals induced by the impact of alkali ions is particularly suitable for studies of this sub-threshold region because, due to their low ionization potential, these ions lack enough potential energy to give rise to the so called potential electron emission (PEE). Alkali projectiles are therefore well suited to study KEE but, despite of this distinctive advantage, such studies have been undertaken only recently.

Relevant experimental studies of KEE investigated the emission induced by the impact of Na^+ ions on a Ru metal surface. These experiments showed that electron emission yields decrease exponentially with the reciprocal of projectile velocity *1/v*. An exponential trend with *1/v* had been previously reported for the yields induced by non metallic projectiles on Au surfaces. Theoretical interpretations of the exponential behaviour shown by electron yields from metal

surfaces have been attempted, considering non-adiabatic one-electron excitations. However, the contributions of these processes have been found to be small when realistic particle-substrate parameters are used and, contrary to experiments, the predicted yield decreases with the increasing impact angle with respect to the surface normal.

The difficulties in interpreting KEE in terms of one-electron excitation indicate that the electron emission could be a more complex many-electron process where electron-electron interactions play an important role. Because there is a lack of any comprehensive many-electron theory of the excitation induced by an atomic particle passing through the electron gas, recently a simplified thermal "hot-spot" model has been used to discuss experimental yield in the case of Na ions impact on Ru.

The interpretation of electron emission yields is further complicated by the difficulty to disentangle contributions arising from different KEE processes as testified by the recent debate about the competition of electron promotion and the other sub-threshold processes. We measured energy distribution and yields of electron emission in the interaction of Na^+ ions with Al surface, showing that electron emission is dominated by electron-promotion processes. The comparison of the yields due to Na ions impact on Al surfaces with that due to Na impact on gold surfaces allows to establish the role of different processes. In the case of Na-Al system, electron emission is mainly determined by electron promotion effects, resulting in emission yields that are significantly higher than those observed in the case of gold target, where electron promotion can be excluded. At impact energies below the promotion thresholds, electron emission yields for Na^+-Al appear to be very similar to that for the Na^+-Au system. We have shown that the "hot-spot model" gives a good account of the experimental data. In particular, the model reproduces quantitatively the exponential decrease of the yields with the inverse of the velocity of incoming projectiles. The other models of the sub-threshold KEE, which are based on the effect of one-electron dynamical scattering in the substrate atomic lattices, would be also interesting to compare with experiments but the comparison is still practically very difficult because they have not been formulated in an analytical form.

5.2.3 Charge transfer processes

Resonant neutralization of hyperthermal Na^+ ions impinging on clean Cu(100) surfaces was studied, focussing on long lived electronic interactions involving the projectile and a target atom. Specific trajectories were considered where the incident particle undergoes multiple collisions within the first surface layers, interacting simultaneously with several target atoms, which leads to single emission of a surface atom that can resonantly exchange charge with both the solid and the projectile. The system was described via a semi-empirical, one-electron potential that includes the effect of a plane metal surface, with projected band gap, the projectile, whose charge state will be eventually investigated, and the substrate atom. On this basis, a model Hamiltonian of the Anderson–Newns type was constructed and the calculated neutralization probability was compared with the angle resolved neutral fraction measured by Keller et al. [C.A. Keller, C.A. Di Rubio, G.A. Kimmel, B.H. Cooper, Phys. Rev. Lett. 75 (1995) 1654]. Subsequently, we presented a more general analysis of the model based on a wave-packet propagation approach.

5.3 PHOTON-MATTER INTERACTION: ELECTRONIC PROPERTIES OF GRAPHENE AND RELATED MATERIALS

This research line concerns with the study of the electronic properties of graphene and related materials by means of synchrotron radiation. Specifically, graphene flakes prepared by the exfoliation method and epitaxially grown on transition metals have been studied through the photoemission and photoabsorption process induced by a synchrotron light source.

In collaboration with the *Istituto di Struttura della Materia*-CNR of Trieste, we have investigated the electronic structure of graphene epitaxially grown on selected transition metals surfaces at the beam line *VUV Photoemission* of the Synchrotron *Elettra*, by means of Angular Resolved Photoemission Spectroscopy (ARPES). This technique has probably contributed more than any other experimental tool to verify the notion of the electronic bands and of some other fundamental concepts, like crystal momentum, Umklapp processes or the Brillouin zone. Thanks to the development of experimental equipments, nowadays ARPES can explore subtle many-body effects, which challenge our understanding of band theory. A photoemission spectrum is in fact directly related to the one particle spectral function $A(k, \omega)$, a fundamental theoretical quantity which contains exhaustive information on the excitation spectrum of a many body system, and therefore of the nature and strength of the interactions. In particular, if the experimental energy and momentum resolution are sufficiently high, ARPES can probe the fundamental quasiparticle states (or signal their absence), which determine the thermodynamic properties of a material; hence, this method is ideal to investigate the conical dispersion of the π band of graphene at the K point of the Brillouin zone. The properties of the quasiparticles may be altered through periodic potentials or destroyed by interaction with the substrate. In these cases, the quasiparticles can be described by one-single electron wave function and the electron charge density is, to some extent, uniformly distributed over the whole surface. In order to investigate the intriguing effect of a modulated potential on the electronic structure of graphene, we have performed ARPES investigations of graphene epixially grown on Ru(0001)

and Ir(111). On Ru(0001) we have showed how a strong buckling of graphene leads to two distinct π-states with different electronic behaviour. The first is quasi-free electron like, displays sharp Dirac cones, and is formed by the stacking areas where the carbon layer floats on the metallic substrate. The second is strongly hybridized and originates from the firmly bound stacking areas of the moiré superstructure. On Ir(111) we have successfully perturbed a graphene layer by self-assembled Ir cluster superlattices. We showed that the cluster superpotential induces highly-anisostropic Dirac cones and affects the electronic band dispersions and the bandgaps of graphene.

The counterpart of the electronic structure above the Fermi level can be probed in a Near edge X-ray Absorption Fine Structure (NEXAFS) investigation, which reveals the total density of empty states. During a NEXAFS experiment, by exciting the C1s level, the dipole scattering rule combined with the highly localized distribution of the 1s wave function results in spectra which will characterize the local density of empty π^* and σ^* states at carbon sites. Experimental investigations carried out in 2009 at the *Swiss Light Source* have contributed in understanding the photoabsorption spectrum of graphene end few-layer graphene samples. Specifically, we have showed the NEXAFS spectrum of graphene and its evolution as a function of the number of layers and of the polarization of the light.

5.4 QUANTUM COHERENCE AND CORRELATIONS IN CONDENSED MATTER SYSTEMS

This research line concerns the theoretical investigation of the role of quantum coherence and correlations (entanglement) in the condensed matter physics of both few and many body systems. The two main themes of the research performed in 2009 have been: (1) Quantum correlations in spin systems; (2) Decoherence and Entanglement in spin-boson systems.

5.4.1 Quantum correlations in spin systems

We analyzed the finite size quantum instability of a spin chain undergoing a topological quantum phase transition of the BKT type, manifested as a sequence of magnetization and entanglement jumps when the magnetic field is varied. We have also shown the occurrence of edge entanglement and argued that this is a direct one-dimensional manifestation of the topological character of the transition. We have also discussed the effect of local magnetic impurities on the behavior of the system and in particular for the transmission of quantum information through the chain, and found out that the modifications induced in the spatial pattern of the spin waves can help to transfer entanglement towards a selected
receiving site.

5.4.2 Decoherence and Entanglement in spin-boson systems

We have studied the behavior of quantum coherence and entanglement for qubits coupled to non-markovian environments and discussed ways to avoid the decoherence. Specifically, we studied the dynamics of two atoms (a qubit pair) spontaneously emitting into a lossy cavity, and we have shown that the entanglement decay can be controlled by detuning the atoms from the cavity field. Furthermore, we have analyzed the specific experimental conditions to implement such a behavior in the context of ion-cavity-QED.

5.5 ION-MATTER INTERACTION

5.5.1 Ion interaction with nanostructures

In synchrotrons and colliders, beams of charged particles circulate in a storage ring in circumference in cold bore vacuum chambers. The relativistic particles emit synchrotron radiations which deteriorate the vacuum by desorbing gases such as H2, CO2, CO, H2O and CH4 from the walls. A solution of this problem is the installation of cryosorbers in the collider on cryogenic elements operating at very low temperatures. Several types of cryosorbers have been studied since a few years. Due to its high specific surface area and large pore volume, porous carbon is considered as a good adsorbent. Our research has been carried out with a Temperature Programmed Desorption (TPD) study on H2 adsorption on multiwalled carbon nanotubes (MWNT) at very low pressure (<10-6 Torr) and temperature (12-30 K). Our results show a hydrogen take up limit in the range of 10-8 mol per gram depending on the adsorption temperature. We compare the MWNT cryosorption capacity with that of commonly used activated carbon and discuss the possibility of employing MWNT as cryosorber in large particle accelerators.

Carbon nanotubes (CNTs) have been studied for their electrical and optical properties. Single walled carbon nanotubes (SWNT) are elongated-shape members of the fullerene family. The properties of SWNT derive from their simple, rigid, nanometre-scale structure: a simple layer of carbon atoms rolled up to form a long cylinder. In particular the electronic and electrical properties are strongly influenced by tube diameter and chirality (which characterize the rolling directions). For instance, it is known that in a SWNT mat, the ratio between the conducting and semiconducting

CNT is 1:2 and that semiconducting species show a band gap with an energy depending on diameter/chirality ratio. In our work we present a study of transport properties modification of Single-Wall Carbon Nanotubes (SWNT) interacting with the most common used alkali metals. We report resistivity measurements of SWNT mats as a function of Na, K, Cs and Li doping. Our results show that as alkali exposure increases, the doped sample resistance decreases, denoting a progressive sample metallization. Furthermore, the resistivity depends upon the deposited alkali species. We hypothesize that both atomic radius and specific conductivity of doping species can affect the transport properties.

Usually, three different techniques are widely applied to study the H2 adsorption rate, capacity, sticking and capture probability, and storage in solids: the volumetric method, which measures the pressure drop owing to hydrogen absorption after loading the specimen contained in a constant volume; the gravimetric method, which measures the sample weight changes due to absorption or desorption; and the temperature programmed desorption (TPD) technique. This latest measures the hydrogen signal during desorption in high vacuum using mass spectrometry; it is highly sensitive allowing one to study samples with masses even below 1 mg and is especially suited for loading of small quantities at low pressures. In our experimental study, H2 adsorption on multiwalled carbon nanotubes (MWCNTs) at low temperatures (12–30 K) and low pressures (2 _ 10_5 Torr) has been studied using the

temperature programmed desorption technique. Our results show that the molecular hydrogen uptake increases nearly exponentially from 6 _ 10_9 wt:% at 24.5 K to 2 _ 10_7 wt:% at 12.5 K and that the desorption kinetics is of the first order. Comparative measurements indicate that MWCNTs have an adsorption capacity about two orders higher than that of activated carbon (charcoal) making them a possible candidate as hydrogen cryosorber for eventual applications in accelerators and synchrotrons.

Many SWCNTs can be packed together into bundles in which they are weakly bonded in a triangular lattice. These tubular objects can be as long as many lm or even up to some mm so that they are typical one dimensional systems. The remarkable properties of these materials open up unprecedented great prospective for possible technological applications. We studied Nitrogen doping of single walled carbon nanotubes by 300 eV N2 ion implantation has been studied with X-ray photoelectron spectroscopy. We investigated the nitrogen doping concentration in the range of 1.5–11.3 at.% and post-irradiation annealing up to 1000 °C. We found that nitrogen atoms can be substitutionally inserted into the perfect sp2 hexagonal network, or bind to two sp2 carbon neighbors in a pyridine-like configuration, or be connected to three or four sp3 carbon atoms in a reconstructed double vacancy site and that the substitutional doping is the most stable bonding against high temperature annealing.

5.5.2 Ion interaction with solids

In particle accelerators with intense and positively charged bunched beams, the emitted synchrotron radiation can produce photoelectrons from the walls of the vacuum system. These electrons can be accelerated toward the opposite walls by the positive space charge of the bunched beam . If the secondary electron yield (SEY) at the walls of the vacuum chamber, i.e. the number of emitted electrons per incident electron, is larger than unity, then the electron population grows rapidly creating an electron cloud (EC) of high density. In our results we report experiments of 200 eV electron bombardment on surface of a real Cu sample used in the Large Hadron Collider (LHC) beam screen. Incidence angle dependent energy distribution curves of emitted electrons were measured and analyzed by separation into three energy regions of conventionally termed elastically reflected, rediffused and true-secondary electrons. Different angular dependences were observed for the three components. These results should have implications in simulation codes of the electron cloud effect in particle accelerators.

Interaction of alkali metal atoms with carbon structures actually holds an important role in scientific research because of its implications in advanced technological applications. The interest in these intercalated compounds is due to changes in electronic and mechanical properties induced by the intercalates, which can lead to technological applications of the new materials.

In particular alkali metals have been widely studied because they can act as potential donors when intercalated within graphite layers and because of their importance in catalysis and hydrogen adsorption processes. In addition, technological applications of lithium graphite compounds have been introduced as rechargeable solid state Li+ batteries. Recently, the studies of carbon nanotubes have attracted much interest as energy storage and nanoscale device applications. At room temperature, alkali deposition on graphite is scarcely studied, while recent studies of alkali deposition on carbon nanotubes showed a rapid diffusion of alkali in the bulk and changes in electronic properties.

Further, the resistivity of carbon nanotubes decreases upon exposure to alkali metals denoting a progressive sample metallization; the most significant change in resistivity occurring for sodium exposure.

We have studied the changes in carbon structure properties after sodium exposure and implantation at room temperature employing the CEAES technique (Collisionally Excited Autoionization Electron Spectroscopy).

Through this spectroscopy we are able to study changes of the sample local electrostatic potential (work function) and provide information about the homogeneity of the sample region beneath the decaying atoms.

We observe that the concentration of implanted alkali atoms is larger for amorphous graphite, suggesting that the efficacy of doping decreases with the structure order and that, contrary to the case of alkali deposition on metal

surfaces, where alkali atoms group together to form islands, Na atoms evaporated on carbon structures diffuse into the bulk.

5.6 MULTIMEDIAL EDUCATION

Increasingly thorough and widespread research has shown that the majority of students has difficulty to learn essential physical concepts in the best of our traditional courses where students read textbooks, solve textbook problems, listen to well-prepared lectures, and do traditional laboratory activities. Education research in physics has shown that learning environments that engage students and allow them to take an active part in their learning process can lead to large conceptual gains compared to traditional instruction. Moreover, in literature has been shown that the direct learner involvement in building interpretative activities promotes formal thinking in the learning process. An active learning environment is often difficult to achieve in lecture sessions, but low-tech and easy to do real experiments have proved to be really effective to create an active learning environment with successful results both in large and smaller high school classes and in classes for pre-service and in-service teachers. Experimental activities have a crucial role in physics education, because they represent one of the methods peculiar to discipline and facilitate the connection between experience and interpretation. They acquire particular significance if related and linked to every day experience. In this context we propose a reasoned sequence of experiences based on easy found and low cost materials, suitable to shed light on essential concepts connected to a variety of physics fields. All illustrated four didactic proposals are carried out by using tinplate jars and each one drives at an integrated balancing between formal and informal education by scheduling various teaching methodologies in order to engage students having different learning styles. In a subsequent work we report on the implementation and early assessment of a multimedia learning object, developed using the Java programming language, which also integrates in a creative way some internet freely available educational resources, intended to support the teaching/learning process of the historical Hertz experiment.

5.7 CULTURAL HERITAGE

Concerning the activity in Cultural Heritage, ceramic layers and decoration pigments of pottery fragments recovered from a Longbard settlement have been studied by Scanning Electron Microscopy (SEM) techniques applied to fractured samples. The samples were fractured just before the measurements and so materials of the site where the fragments have been obtained did not contaminate the analysed surfaces, given the brief exposition to air. The samples consisted of two terracottae and a ceramic fragment from graves of the excavation site. The terracottae contained different decorations: the bigger one was decorated with a so-called “brown band” decoration, while the smaller was decorated with a “red band” decoration. The third fragment was a terracotta bulk with a ceramic layer superimposed on it along with a clearly more visible decoration with respect to the other samples. The results show that the bulks of the analysed samples were composed of the usual silicates with very small and peculiar silver grains widely distributed within the bulk of the terracottae. Whilst the ceramic fragment comprises the same bulk structure, its surface layer shows the presence of lead, but no traces of tin have been found in this layer or in the bulk of this sample. In the decoration of this sample, the detection of heavy elements is very scarce. The terracotta fragments have the same bulk structure (including the presence of the silver grains), while the decorations of such samples show the presence of iron in both “brown band” and “red band”, with the iron content being greater in the latter band. Interestingly, since red ochre can brownish if it is burnt, no manganese has been detected in both samples so that the “brown band” can be only a burned “red band”. Moreover diagnostic studies have been performed on an ancient coin in order to find if the coin is authentic or is a coinage proof. Our investigation includes Scanning Electron Microscopy – Energy Dispersive X-ray (SEM-EDX) and Cathodoluminescence (CL). The coin is a Drachma representing on the obverse the portrait of Poseidon and, on the reverse the figure of Anfitrite riding a seahorse while Eros is shooting an arrow. The coin is well known in the numismatic studies and originals can also be found in Catanzaro, Naples or Milan museums. The EDX analysis, executed on narrow points of the surface, revealed Pb and Cu as main components of the coin on both side: 51% of Pb and 35% of Cu their weight. Surprisingly on both sides we found traces of gold. The maximum dimensions and the percentage in weight of the small revealed gold spots were respectively on the order of 20 μm and 95%. At the same time on these spots was executed luminescence emission induced by electron bombardment (CL). This analysis confirmed SEM results, even if, the presence of Au was more evident than in SEM analysis. In fact CL analysis showed a little presence of Au overall the sample surface.

A. PUBLICATIONS ON SCIENTIFIC JOURNALS

A.1 Publications on international journals

A.1.1 Publications on international journals printed in 2009

1. W. Son, L. Amico, F. Plastina, and V. Vedral,
   Quantum instability and edge entanglement in the quasi-long-range order,
   Phys. Rev. A 79, 022302 (2009).
   Also selected by Virtual Journal of Quantum Information, Vol. 9, Issue 2, 2009.

2. F. Francica, S. Maniscalco, J. Piilo, F. Plastina, and K.-A. Suominen,
   Off-resonant entanglement generation in a lossy cavity,
   Phys. Rev. A 79, 032310 (2009).
   Also selected by Virtual Journal of Quantum Information, Vol. 9, Issue 3, 2009.

3. K. Harkonen, F. Plastina, and S. Maniscalco,
   Dicke model and environment-induced entanglement in ion-cavity QED,
   Phys. Rev. A 80, 033841 (2009).
   Also selected by Virtual Journal of Quantum Information, Vol. 9, Issue 10, 2009.

4. M. Barberio, P. Barone, A. Bonanno, M. Camarca,E. Masciari, A. Oliva, F. Xu,
   Transport Properties of alkali-doped- single wall carbon nanotubes mats,
   Superlattices And Microstructures 46 (2009) 369-373

5. M. Barberio, P. Barone, A. Bonanno and F. Xu,
   Oxygen Interaction with Single Walled Carbon Nanotubes,
   Superlattices and Microstructures 46 (2009) 365-368

6. A. Bonanno, M. Barberio, P. Barone, M. Camarca, D. R.Grosso, R. Vasta, F. Xu, and A. Oliva,
   Changes in electronic properties of carbon structures by evaporation and implantation of alkali metals,
   Vacuum, DOI: 10.1016/j.vacuum.2009.10.039 (in press)

7. A. Bonanno, G. Bozzo, M. Camarca, and P. Sapia,
   Weighting magnetic interactions,
   Physics Education 44 (2009) 570-572.

8. M. Camarca, A. Bonanno, P. Sapia,
   Reference frame symmetries and conservation laws: Galilean versus Lorentzian,
   Eur. J. Phys. 30 (2009) 1137-1142.

9. M. Pisarra, M. Commisso, A. Sindona, P. Riccardi, Z. Sroubek,
   Kinetic electron emission from metal surfaces by slow Na^+ ions
   Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, Volume 267, Issues 8-9, 1 May 2009, Pages 1721-1724

10. A. Sindona, P. Riccardi, S. Maletta, G. Falcone,
    Double resonant neutralization in hyperthermal energy alkali ion scattering at clean metal surfaces
    Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, Volume 267, Issue 4, February 2009, Pages 578-583

11. M. Papagno, A. Fraile Rodríguez, C. O. Girit, J. C. Meyer, A. Zettl and D. Pacilé,
    Polarization-dependent C K near-edge X-ray absorption fine-structure of graphene
    Chem. Phys. Lett. 475 (2009) 269-271

12. D. Pacilé, M. Papagno, A. Fraile Rodríguez, M. Grioni, L. Papagno, C. O. Girit, J. C. Meyer, G. E. Begtrup, and A. Zettl
    Near-edge x-ray absorption fine-structure investigation of graphene-Pacilé et al Reply
    Phys. Rev. Lett. 102 (2009) 099702

A.1.2 Publications on international journals accepted in 2009

1. G. Liberti, F. Piperno, and F. Plastina,
   Finite size behavior of collective quantum spin system,
   to be published by Phys. Rev. A.

2. F. Francica, S. Maniscalco, F. Platina,
   Off-resonant quantum Zeno and anti-Zeno effects on the entanglement,
   to be published by Physica Scripta.

3. F. Plastina, G. Falcone, F. Francica, G. Liberti, F. Piperno, and S. Maniscalco,
   Cavity induced quantum cooperative phenomena,
   to be published by Physica Scripta

4. D. Giuliano , A. Sindona, G. Falcone, F. Plastina and L. Amico,
   Entanglement in spin system with inverse-square statistics interaction,
   to be published by New Journal of Physics.

5. A. Cupolillo, M. Pisarra, A. Sindona, M. Commisso, P. Riccardi,
   Electron excitation in the interaction of slow ions and electrons with metals and monolayer graphite on Ni(111) surfaces
   to be published by Vacuum

6. A. Sindona, P. Riccardi, S. Maletta, M. Pisarra, A. Cupolillo,
   Wave-packet study of hyperthermal alkali ion neutralization at metal surfaces
   to be published by Vacuum.

7. C. Giallombardo, A. Cupolillo, L. Papagno
   Oxygen-driven surface segregation of lithium from single-wall carbon nanotubes
   to be published by Diamond and Related Materials

8. M. Castriota, E. Cazzanelli, D. Pacilé, L. Papagno, C. O. Girit, J. C. Meyer, A. Zettl , M. Giarola and G. Mariotto
   Spatial dependence of observed Raman frequencies and disorder in graphene monolayers
   to be published by Diam. and Relat. Mat.

A.1.3 Papers submitted for publication in 2009

1.. G. Chidichimo, P. Barone, M. Barberio et al.,
   Spectroscopic and Kinetic Investigation of Ethyl Viologen Reduction in Novel Electrochromic Plastic Films,
   submitted to Journal of Physical Chemistry.

2. P. Barone, M. Barberio et al.,
   Behavior of electrochromic devices under current and voltage supply,
   Submitted to Journal of Applied Physics.

3. P. Riccardi, M. Pisarra, A. Cupolillo, M. Commisso, A. Sindona, R.A. Baragiola, C.A. Dukes
   Secondary Electron Emission Spectra from Clean and Cesiated Al Surfaces: Role of Plasmon Decay and Data Analysis for Practical Purposes
   Submitted to Journal of Physics-Condensed Matter

B PUBLICATIONS ON CONFERENCE PROCEEDINGS

B.1 Publications on international conference proceedings in 2009

1. F. Plastina, T.J.G. Apollaro,
   Storage and transmission of entanglement in a spin chain,
   in "Quantum Communication, Measurement and Computing", Proceedings of the "QCMC 2008" Conference, A. Lvovsky (ed), AIP (2009), pag. 17.

2. A. Bonanno, M. Barberio, P. Barone, M. Camarca, D. R.Grosso, R. Vasta, F. Xu, and A. Oliva,
   Changes in electronic properties of carbon structures by evaporation and implantation of alkali metals,
   ECOSS, Parma, September 2009)

3. A. Bonanno, M. Barberio, P. Barone, M. Camarca, D. R.Grosso, R. Vasta, F. Xu, and A. Oliva,
   Changes in electronic properties of carbon structures by evaporation and implantation of alkali metals,
   ACSin-10, Granada, September 2009

4. M. Goffredo, M. Albanese, D. Infante, G. Bozzo,
   Teaching Physics in a CLIL/Blended Learning Environment at Primary School,
   Proceedings of the ″14th International Conference on **M**ultimedia in **P**hysics **T**eaching and **L**earning", Udine, September 23-25, 2009.

5. A. Bonanno, G. Bozzo, M. Camarca and P. Sapia:
   An on-line experiment on electromagnetic induction,
   Proceedings of the ″14th International Conference on **M**ultimedia in **P**hysics **T**eaching and **L**earning", Udine, September 23-25, 2009.

6. G. Bozzo, G. Meneghin, M. Meneghin and S. Vercellati:
   Animate the formal tools to reconcile the local observation to the study of motion in physics,
   Proceedings of the ″14th International Conference on **M**ultimedia in **P**hysics **T**eaching and **L**earning", Udine, September 23-25, 2009.

7. A. Bonanno, G. Bozzo, M. Camarca and P. Sapia:
   Magnetic interactions: a multimedia interactive tutorial,
   Proceedings of the ″14th International Conference on **M**ultimedia in **P**hysics **T**eaching and **L**earning", Udine, September 23-25, 2009.

8. A. Bonanno, G. Bozzo, M. Camarca and P. Sapia:
   Energy conversion and rotational mechanic measurement with a common DC motor,
   Proceedings of the ″14th International Conference on **M**ultimedia in **P**hysics **T**eaching and **L**earning", Udine, September 23-25, 2009.

9. G. Bozzo, M. Michelini, A. Stefanel,
   On-line sensor to bridge primary students from a local vision to a global one on thermal processes,
   ESERA 2009

10. A. Bonanno, G. Bozzo, M. Camarca, M. Michelini and P. Sapia:
    A simple and innovative magnetic explorer,
    GIREP-EPEC 2009 International Conference, Leicester UK – August 17-21, 2009.

11. A. Bonanno, G. Bozzo, M. Camarca, M. Michelini and P. Sapia:
    How students interpret a simple situation of induction phenomena,
    GIREP-EPEC 2009 International Conference, Leicester UK – August 17-21, 2009.

12. G. Bozzo, R. Viola,
    Training teachers interpret a simple situation of induction phenomena in a PCK activity,
    STE – Modena 2009

13. V. Pingitore, A. Bloise, E. Barrese, C. Apollaro, D. Miriello,
    Flux growth and characterization of Ti- and Ni- doped enstatite single crystals,
    Convegno "FIST", Rimini 2009

14. V. Pingitore, D. Miriello, F. Chiaravalloti, A. Bloise, D. Barca, G.M. Crisci, A. Oliva,
    Characterization of magnetic microspherules: preliminary results,
    Geoitalia, Rimini 2009

15. E. Frantzeskakis, L. Moreschini, M. C. Falub, M. Grioni, S. Pons, C. R. Ast, D. Pacilé, M. Papagno,

New mechanism for spin-orbit splitting of conduction states in surface alloys
e-J. Surf. Sci. Nanotech. "Conference-ICSFS-14", Dublin, 2009, Vol. 7, pp. 264-268.

C INVITED PRESENTATIONS

C.1 Invited presentations at international conferences in 2009

1. F. Plastina,
   Cooperative effects in cavity,
   CEWQO 2009, Turku (Finland), May 23, 2009

2. A. Bonanno, M. Barberio, P. Barone, M. Camarca, D. R.Grosso, R. Vasta, F. Xu, and A. Oliva,
   Changes in electronic properties of carbon structures by evaporation and implantation of alkali metals,
   Ion-surface interactions (ISI0, Moscow, August 2009)

3. P. Riccardi, A. Cupolillo, M. Pisarra, A. Sindona, M. Commisso,
   Electron excitation in the interaction of slow ions and electrons with metals and monolayer graphite on Ni(111) surfaces,
   Ion-surface interactions (ISI0, Moscow, August 2009)

D PRESENTATIONS AT CONFERENCES

D.1 Presentations at international conferences in 2009

1. A. Bonanno, M. Barberio, P. Barone, M. Camarca, D. R.Grosso, R. Vasta, F. Xu, and A. Oliva,
   Changes in electronic properties of carbon structures by evaporation and implantation of alkali metals,
   Ion-surface interactions (ISI), Moscow, August 2009

2. A. Bonanno, G. Bozzo, M. Camarca, M. Michelini and P. Sapia,
   A simple and innovative magnetic explorer,
   GIREP-EPEC 2009 International Conference, Leicester UK – August 17-21, 2009.

3. A. Bonanno, G. Bozzo, M. Camarca, M. Michelini and P. Sapia,
   How students interpret a simple situation of induction phenomena,
   GIREP-EPEC 2009 International Conference, Leicester UK – August 17-21, 2009.

4. A. Bonanno, G. Bozzo, M. Camarca and P. Sapia,
   An on-line experiment on electromagnetic induction,
   14th International Conference on **M**ultimedia in **P**hysics **T**eaching and **L**earning, Udine, September 23-25, 2009.

5. A. Bonanno, G. Bozzo, M. Camarca and P. Sapia,
   Magnetic interactions: a multimedia interactive tutorial, 14th International Conference on **M**ultimedia in **P**hysics **T**eaching and **L**earning, Udine, September 23-25, 2009.

6. P. Riccardi, A. Cupolillo, M. Pisarra, A. Sindona, M. Commisso,
   Electron excitation in the interaction of slow ions and electrons with metals and monolayer graphite on Ni(111) surfaces,
   Ion-surface interactions (ISI0, Moscow, August 2009)

7. A. Sindona, P. Riccardi, S. Maletta, M. Pisarra, A. Cupolillo,
   Wave-packet study of hyperthermal alkali ion neutralization at metal surfaces,
   Ion-surface interactions (ISI0, Moscow, August 2009)

D.2 Poster Presentations at international conferences in 2009

1. F. Francica,
   Off-resonant quantum Zeno and anti-Zeno effects on the entanglement,
   CEWQO 2009, Turku (Finland), May 24, 2009

2. A. Bonanno, M. Barberio, P. Barone, M. Camarca, D. R.Grosso, R. Vasta, F. Xu, and A. Oliva, *Changes in electronic properties of carbon structures by evaporation and implantation of alkali metals* , ECOSS, Parma, September 2009

3. A. Bonanno, M. Barberio, P. Barone, M. Camarca, D. R.Grosso, R. Vasta, F. Xu, and A. Oliva, *Changes in electronic properties of carbon structures by evaporation and implantation of alkali metals* , ACSin-10, Granada, September 2009

D.2 Presentations at national conferences in 2009

1. F. Plastina,
Local vs. Global control of entanglement in spin chains,
Problemi attuali di Fisica Teorica, Vietri sul mare (SA), April 4, 2009

2. F. Plastina,
Quantum Cooperative effects in cavity,
Italian quantum information science conference 2009, Pisa, Novembre 7, 2009.

3. G. Bozzo, G. Meneghin, M. Nichelini, S. Vercellati,
Animare gli strumenti formali per raccordare l'osservazione locale allo studio del moto in fisica,
DIDAMATICA 2009

6. MOLECULAR BIOPHYSICS

Professors and Researchers:	Luigi Sportelli Rosa Bartucci Rita Guzzi Bruno Rizzuti (Lab. Licryl, CNR-INFM, Cosenza)
Undergraduate Students:	Stefania Evoli Matteo Rescia Tania Basile
Technical staff:	Bruno De Nardo Massimo Sposato
Collaborators:	D. Marsh (*MPI for Biophysical Chemistry, Goettingen, Germany*) M. Esmann (*Aarhus University, Dept. of Biochemistry, Denmark)* C. Dennison, K. Sato (*Institute for Cell and Molecular Biosciences, Newcastle University, UK*) A. Russo, G. Sindona (*Dept. of Chemistry*, *University of Calabria)* M.P. De Santo, B. Zappone *(Lab. Licryl, CNR-INFM, Cosenza)* E. Perri (*Centro di Ricerca per l'Olivicoltura e l'Industria Olearia, Rende (Cs)*) M. Pantusa, A. Stirpe (*Post-Doc)*

Introduction

In the year 2009 the research activity of the Molecular Biophysics Group has essentially been focused on three main topics:

6.1. Molecular interactions at the lipid/protein interface

6.2. Thermostability, aggregation and molecular dynamics simulation of proteins.

6.3. Food Biophysics

The first research project was mainly concerned with the study of the process of transfer of amphiphilic molecules between donor and acceptor biosystems such as carrier proteins and liposomes sterically stabilized by polymer-lipids. The perturbation of a denaturant on the conformational heterogeneity of Na,K-ATPase enzymes at cryogenic temperatures has also been investigated by pulsed EPR methods.

The second one has been focused on the investigation of thermal stability of the copper-binding loop mutants of azurin, on the effects of Cu(II) ions on the thermal aggregation of human serum albumin, on the molecular dynamics of the interaction of albumin with fatty acids, together with SEM investigations of native □-lactoglobulin adsorbed on silicon and mica inorganic surfaces to elucidate the role played by the physical properties of solid surfaces on its aggregation.

In the third research activity, the effects of aromatic amino acid (Trp, Tyr, His) containing di-peptides and of hydrophobic di-peptides on the oxidation of Linoleic acid have been studied with Electron Spin Resonance (ESR) spectroscopy using the spin trap technique with the aim to evidence the role of amino acid side chains on fat acid oxidation.

In the following, the main research results obtained during the investigation are briefly presented in form of abstracts.

6.1. MOLECULAR INTERACTIONS AT THE LIPID/PROTEIN INTERFACE

6.1.1 Kinetics of stearic acids transfer between human serum albumin and sterically stabilized liposomes

The kinetics of the transfer of stearic acids between human serum albumin (HSA) and the long circulating sterically stabilized liposomes (SSL) composed of dipalmitoylphosphatidylcholine (DPPC) and of submicellar content of the polymer-lipid poly(ethylene glycol:2000)-dipalmitoylphosphatidylethanolamine (PEG:2000-DPPE) has been studied by fluorescence spectroscopy. The study exploits the fact that HSA has a single tryptophan (Trp) residue and that the intrinsic Trp-emission intensity is quenched by the presence of doxyl spin-labelled stearic acids (SASL). Protein/lipid dispersions are considered in which SASL molecules are inserted either in the protein or in the SSL and the transfer of SASL between the protein and SSL is conveniently monitored by the time-variation of the inherent Trp-fluorescence intensity of HSA. It is found that the transfer of fatty acids between HSA and SSL depends on the type of donor and acceptor matrix, on the temperature (i.e., on the physical state of the lipid bilayers), and on the grafting

density of the PEG-lipids at the lipid/protein interface. In the absence of polymer-lipids, the rate of transfer increases with temperature in both directions of transfer and it is higher for the passage from DPPC bilayers to HSA. The presence of polymer-lipids reduces the rate of transfer both in the mushroom and in the brush regime of the polymer-chains, especially at low graftig density and for lipid membranes in the fluid phase.

6.1.2 Spin-echo EPR of Na,K-ATPase unfolding by urea

Denaturant-perturbation and pulsed EPR spectroscopy are combined to probe the folding of the membrane-bound Na,K-ATPase active-transport system. The Na,K-ATPase enzymes from shark salt gland and pig kidney are covalently spin-labelled on cysteine residues that either do not perturb, or are essential to hydrolytic activity (Class-I and Class-II –SH groups, respectively). Urea increases the accessibility of water to the spin-labelled groups and increases their mutual separations, as recorded by D_2O-interactions from ESEEM spectroscopy and instantaneous spin diffusion from echo-detected EPR spectra, respectively. The greater effects of urea are experienced by Class-I groups, which suggests preferential unfolding of the extramembrane domains. Conformational heterogeneity induced by urea causes dispersion in spin-echo phase-memory times to persist to higher temperatures. Analysis of lineshapes from partially relaxed echo-detected EPR spectra indicates that perturbation by urea enhances the amplitude and rate of fluctuations between conformational substates, in the higher temperature regime, and also depresses the glasslike transition in the protein. These non-native substates that are promoted by urea lie off the enzymatic pathway and contribute to the loss of function.

6.2. THERMOSTABILITY, AGGREGATION AND MOLECULAR DYNAMICS SIMULATION OF PROTEINS

6.2.1 Thermal aggregation and fibril formation in human serum albumin (HSA). Effect of divalent copper ions

Protein aggregation and fibril formation are among some of the most recurrent topics in multidisciplinary studies, both in the basic research and in the biomedical areas. We combine biophysical spectroscopic techniques for studying HSA aggregation as a function of temperature and concentration of Cu(II) ions in the dispersion media. Optical density measurements versus temperature and versus time (at different temperatures) in the absence and in the presence of divalent ions were carried out to investigate the formation of aggregates and the kinetic of protein aggregation. The fluorescence of thioflavin T (ThT), a fibril-specific dye, was employed to assess the amyloid properties of the protein aggregates. The electron paramagnetic resonance (EPR) spectroscopy of the paramagnetic divalent copper ions in protein/metal complexes was used to investigate the binding of the metal to native protein in different experimental conditions. It is found that, at a concentration of 10 mg/ml and at pH 7.2, HSA aggregation starts at a temperature higher of the protein denaturation temperature and is accompanied by a lag phase. Copper reduces the lag phase but it does not influence the kinetics of protein aggregation. The metal favors the formation of HSA fibrils and it remains bound to the protein.

6.2.2 Kinetic stability and activation energy of active site loop mutants of azurin

Loop-directed mutagenesis has been used to insert the amicyanin (AMI) and plastocyanin (PC) type 1 (T1) copper-binding loops into azurin (AZ) to obtain the chimeric variants AZAMI and AZPC, respectively. In both proteins the metal binding site has typical T1 properties and the overall structures of AZAMI and AZPC are remarkably similar to that of AZ. The conformation of the loop in these chimeric proteins resembles that of the native protein. To assess the influence of these loop mutations on stability, the thermal unfolding of AZAMI and AZPC has been investigated by differential scanning calorimetry, optical absorption and fluorescence spectroscopy. The calorimetric profiles of both AZ variants exhibit a complex shape consisting of two endothermic peaks and an exothermic peak. The thermal transition between the native and the denatured states is irreversible and it is scan-rate dependent. The stability of the loop variants is noticeably reduced when compared to the wild type protein. When comparing the temperature of the maximum heat absorption, T_{max}, the single endothermic peak of AZ is at 83.7 °C (at the scan rate of 60 °C/h), whereas for AZAMI and AZPC this peak is at 74.0 °C and 67.0 °C, respectively. The temperature dependence of the absorbance at 608 nm, due to an active site ligand-to-metal transition, in AZAMI and AZPC has a trend similar to that observed for AZ, although the transition temperatures are decreased, especially for AZPC (by about 15 °C). The mutated cupredoxins also exhibit lower stability when investigated by fluorescence spectroscopy. Despite these loop mutations having limited effect on the structure of the metal binding site and the overall protein fold, their consequences on the stability are dramatic both in terms of kinetic stability and unfolding pathway.

6.2.3 The role of Lys525 on the head-group anchoring of fatty acids in the highest affinity binding site of human serum albumin

Human serum albumin provides the transport of long-chain fatty acids in the blood through three high-affinity and four low-affinity binding sites. Molecular dynamics simulations have been performed to investigate the anchoring of palmitic acid molecules to the protein. In the site with the highest affinity, Site 5, the key residue Lys525 not only

binds the head-group of the palmitate ion by electrostatic interactions with its charged terminal group, but it also accommodates the first portion of the lipid chain by non-electrostatic interactions with the rest of its sidechain. The flexibility of Lys525, and in particular of the dihedral angle χ3, is suggested to account for a number of spectroscopic properties observed in correspondence with the entrance of the hydrophobic pocket constituting Site 5.

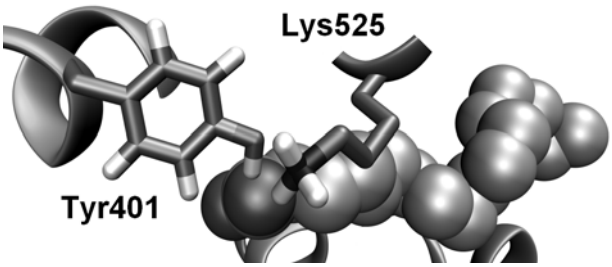

Fig. 1*: Structure of Site 5 in human serum albumin, as obtained in simulation. The fatty acid molecule (Van der Waals representation) and Tyr401 and Lys525 residues (thick licorice representation) are shown.*

6.2.4 Native β-Lactoglobulin self-assembles into a hexagonal columnar phase on a solid surface

Using electron scanning microscopy, we have studied the protein deposit left on silicon and mica substrates by dried droplets of aqueous solutions of bovine β-lactoglobulin at low concentration and pH-values in the range 2-7. We have observed different self-assembled structures: homogeneous layers, hexagonal platelets and flower-shaped patterns laying flat on the surface, and rods formed by columns. Homogeneous layers covered the largest area of the droplet deposit. The other structures were found in small isolated regions, where the protein solution dried in the form of microdroplets. The presence of hexagonal platelets, flower-shaped patterns and columnar rods shows that β-lactoglobulin self-assembles at the surface in a hexagonal columnar phase, which has never been observed in solution. A comparison with proteins showing similar aggregates suggests that β-lactoglobulin structures grow from hexagonal germs composed of discotic nanometric building blocks, possibly possessing an octameric structure. We propose that discotic building blocks of β-lactoglobulin maybe produced by the anisotropic interaction with the solid surface.

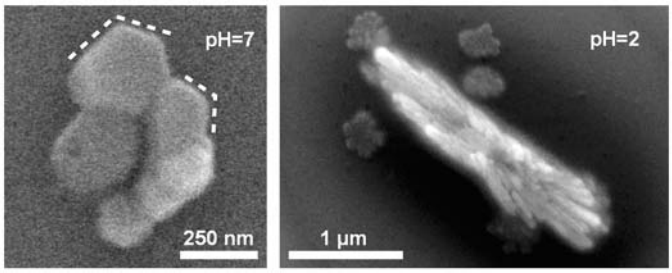

Fig. 2*: Hexagonal structures of β-lactoglobulin: cluster of crystals at neutral pH (left) and multi-columnar rod in coexistence with flower-shaped aggregates at low pH (right).*

6.3. FOOD BIOPHYSICS

6.3.1 Linoleic acid free radicals interacting with aliphatic and aromatic amino acids containing di-peptides. A spin trap ESR investigation

Free radicals are involved in cell ageing as well as in the appearance of several pathologies including heart troubles and cancer. In particular, lipid oxidation plays a fundamental role in the oxidative stress related to such pathologies. In the past year, we have investigated by electron spin resonance spectroscopy with the spin trap technique and Tandem Mass spectrometry the anti-oxidant activity of the aromatic amino acids Trp, Tyr and His in the autoxidation of Linoleic acid and their modulation effects of the Linoleic acid enzymatic oxidation process induced by soybean lipoxygenase type I-B. In the year 2009 the research activity has been focused on the effects of several di-peptides on the autoxidation of Linoleic acid. The techniques used for the study have been, as in the past, the ESR spectroscopy with the use of the spin trap POBN and MS-MS spectrometry as well. The aromatic amino acid containing di-peptides with the second amino acid Ala or Leu, i. e., Trp-, Tyr-, His-Ala and Trp-,Tyr-, His-Leu, have shown that

the efficacy in producing the POBN adducts, as evaluated by measuring the intensity of the first resonance line of the three doublets ESR spectra, is in the order: Trp-Ala > Tyr-Leu > His-Leu. Similar experiments carried out using aliphatic di-peptides have evidenced that the di-peptide Leu-Leu shows the highest anti-oxidant activity.

A PUBLICATIONS ON SCIENTIFIC JOURNALS

A.1 Publications on international journals

A.1.1 Publications on international journals printed in 2009

1. B. Rizzuti, L. Sportelli, R. Guzzi
Molecular dynamics of amicyanin reveals a conserved dynamical core for blue copper proteins
Proteins: Structure, Function and Bioinformatics 74, 961-971 (2009)

2. R. Bartucci, R. Guzzi, L. Sportelli, D. Marsh
Intramembrane water associated with TOAC spin-labeled alamethicin: Electron spin-echo envelope modulation by D_2O
Biophysical Journal 96, 997-1007 (2009)

3. R. Guzzi, R. Bartucci, L. Sportelli, M. Esmann, D. Marsh
Conformational heterogeneity and spin-labelled –SH groups: Pulsed EPR of Na,K-ATPase
Biochemistry 48, 8343-8354 (2009)

A.1.2 Publications on international journals accepted in 2009

1. B. Rizzuti, B. Zappone, M.P. De Santo, R. Guzzi
Native β-lactoglobulin self-assembles into a hexagonal columnar phase on a solid surface.
Langmuir (2009), DOI: 10.1021/la902464f

2. M. Pantusa, A. Stirpe, L. Sportelli, R. Bartucci
Spontaneous transfer of stearic acids between human serum albumin and PEG:2000-grafted DPPC membranes.
European Biophysics Journal with Biophysics Letters (2009), DOI: 10.1007/s00249-009-0442-0

3. B. Rizzuti, M. Pantusa, R. Guzzi
The role of Lys525 on the head-group anchoring of fatty acids in the highest affinity binding site of human serum albumin.
Spectroscopy (2009), accepted

4. A. Russo, S. Caputo, M. Pantusa, E. Perri, G. Sindona, L. Sportelli
Amino acids as modulators of lipoxygenase oxidation mechanism. The identification and structural characterization of spin adducts intermediates by electron spin resonance and tandem mass spectrometry.
Food Chemistry (2009), DOI: 10.1016/j.foodchem.2009.06.065

5. M. Pantusa and R. Bartucci
Kinetics of stearic acids transfer between human serum albumin and sterically stabilized liposomes.
Eur Biophys J (2009), accepted

A.1.3 Publications on international journals submitted in 2009

1. R. Guzzi, M. Babavali, R. Bartucci, L. Sportelli, M. Esmann and D. Marsh
Spin-echo EPR of Na,K-ATPase unfolding by urea
Biophysical J. (2009), submitted

2. R. Guzzi, L. Sportelli, S. Yanagisawa, C. Li, C. Dennison
Kinetic stability and activation energy of active site loop mutants of azurin
BBA-Protein and Proteomics (2009), submitted

D PRESENTATIONS AT CONFERENCES

D.1 Presentations at international conferences in 2009

1. M. Pantusa, L. Sportelli, R. Bartucci
Kinetics of stearic acids transfer between human serum albumin and polymer-grafted membranes
7th European Biophysics Congress, Genova, Italy, July 11–15, 2009

2. A. Stirpe, M. Pantusa, R. Bartucci, L. Sportelli, R. Guzzi
Temperature and metal ions induced aggragation of human serum albumin
7th European Biophysics Congress, Genova, Italy, July 11–15, 2009

3. B. Rizzuti, M. Pantusa, R. Bartucci, L. Sportelli, R. Guzzi
Local flexibility of Human Serum Albumin complexed with fatty acids.
13th ECSBM, Palermo, Italy, August 28–September 2, 2009

4. R. Guzzi, L. Sportelli, C. Dennison
The thermodynamic consequences of loop mutations in azurin
13th ECSBM, Palermo, Italy, August 28–September 2, 2009

D.2 Presentations at national conferences in 2009

1. B. Rizzuti, M. Pantusa, R. Bartucci, L. Sportelli, R. Guzzi
Concerted dynamics of domains and subdomains in human serum albumin.
XCV Congresso Nazionale Società Italiana di Fisica Bari, September 28–October 3, 2009

7. PHYSICS AND APPLICATIONS OF THE SOFT MATTER

Professors and Researchers	Roberto Bartolino Riccardo C. Barberi Lev M. Blinov Enzo Cazzanelli Gabriella Cipparrone Maria Penelope De Santo Pasquale Pagliusi Nicola Scaramuzza Giuseppe Strangi Roberto Caputo Cesare Umeton Carlo Consolato Versace
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PhD students	Stefano D'Elia Luciano De Sio Mario Ariosto Matranga Gaetano Nicastro Luigia Pezzi Tania Rugiero Francesca Teocoli Carbone Francesco Hamdi Ridha Gimenes Lety Emanuela Bruno
Personnel of the CNR-INFM Licryl lab	Federica Ciuchi *(CNR, Cosenza, Italy)* Michele Giocondo *(CNR, Cosenza, Italy)* Giuseppe Lombardo *(CNR, Cosenza, Italy)* Alfredo Mazzulla *(CNR, Cosenza, Italy)* Alfredo Pane *(CNR, Cosenza, Italy)*
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International collaborations	University of Bucharest *(Romania)* LPCM-CNRS, University Bordeaux I *(France)* Center for Bio-Molecular Science and Engineering, Naval Research Lab. Washington D.C. *(USA)* Bulgarian Academy of Sciences - Sofia *(Bulgaria)* Moscow State University *(Russia)* Centre Paul Pascal - Bordeaux *(France)*

University of Colorado - Boulder *(USA)*
University of Tunis *(Tunisia)*
College de France - Paris *(France)*
University of Marseille *(France)*
University of Exeter *(UK)*
Chalmers University - Goteborg *(Sweden)*
University of Kent *(USA)*
Polytechnic of Madrid *(Spain)*
Polytechnic of Bucharest *(Romania)*
University of Gent *(Belgium)*
University of Ljublijana *(Slovenia)*
Russian Academy of Sciences *(Russia)*
University of Tblisi *(Georgia)*
Philips Research Center *(The Netherlands*)
Hewlett Packard Research Center *(UK)*
University of Nizhny - Novgorod *(Russia)*
University of California - Berkeley *(USA)*
University of Nebraska *(USA)*
University of Ohio *(USA)*
University of Mexico–UNAM *(MEX)*
European Synchrotron Radiation Facility *(Francia)*
Rutherford Appleton Laboratory *(UK)*
Stanford Synchrotron Radiation Laboratory *(USA)*

Introduction

The research activity of the group is going towards different fields of the soft matter using the huge experience obtained in a long standing previous activity, specifically in liquid crystals.

Generally speaking the scientific interests of the group can be resumed as in the following:

7.1.1 MATERIALS, IN CLOSE COLLABORATION WITH CHEMIST GROUPS, BOTH FROM UNIVERSITY OF CALABRIA AND FROM OUTSIDE: NEW LIQUID CRYSTALS, COLLOIDAL SYSTEMS, NANOPARTICLES AND LIQUID CRYSTALS, POLYMERS, PHOTOPOLYMERS, BLENDING OF LIQUID CRYSTALS AND POLYMERS….. CHARACTERISATION (DIELECTRIC, RAMAN, ELLIPSOMETRY, ELECTRON MICROSCOPY…)

Raman spectroscopy and thin films synthesis

As a principal task during 2009 researches and experiments have been carried out to optimize some electrochomic device previously developed. Such activity concerns applied research, and links with industry. Awards at local and national level have been gained by the NOTREDAME project (*"**iNnOvative subsTRatEs Development for electro-opticAl polyMeric flexible self consistent devices for applications in the field of the Energy saving**);* such business idea, generated by the previous research in the field of electrochromism has been also inserted in the CRESCITA incubation project, organized by "PARCO SCIENTIFICO E TECNOLOGICO DELLA CALABRIA-CALPARK".

Obviously the preparation for business meetings and presentations of NOTREDAME project drained time and resources, providing, however, remarkable results in terms of group recognition and useful contacts with potential financial supporters .

With regard to the basic research activity on the materials with new electrochemical and electrooptical properties, the current investigations have been developed on various oxides, microcrystals and thin films, having mixed ionic-electronic conduction, or else employed to obtain peculiar performances in electro-optic devices, electrochromics, liquid crystal cells and new photovoltaic layers.

Worth to remark are the study on vanadium oxide nanotubes, growing in particular thermal ranges during the crystallization of amorphous material sinthesized via sol-gel methods, and the micro-Raman characterization of TiO-phthalocianine films deposited on atomically flat mica substrates by a particular technique using high kinetic energy molecular beams.

Quite interesting for the point of view of basic spectroscopy is the discovery of an anomalous Raman enhancement of WO_3 thin films deposited on ITO coated glasses undergoing pre-deposition thermal treatments. Such enhancement appears to be correlated with the formation of sodium oxide island on the pre-treated substrate.

Beside the research on oxide films, the investigation on nanostructured carbon forms (nanotubes, graphene) have been carried out, as well as initial studies on isomorphous materials as BN. For such materials the Raman spectroscopy provide a quite fundamental probe. In particular, we performed a map of the stress on graphene flakes, deposited by the mechanical exfoliation method.

Finally, we must report also the characterization of samples connected to the Italian cultural heritage: a painting of anonymous author of Baroque age, kindly provided by the Museum MAON of Rende, has been investigated: spectroscopic evidences of recent restoration works, undocumented, have been found. Moreover, micro-Raman measurement have been performed on other samples, object of studies by other groups.

Enclosed below is a list of publications on international journals and of various contribution and participations to conferences, workshop and so on.

Ellipsometry investigation of the effects of annealing temperature on the optical properties of indium tin oxide thin films studied by Drude–Lorentz model

Float glass substrates covered by high quality ITO thin films (Balzers) were subjected for an hour to single thermal treatments at different temperature between 100 8C and 600 8C. In order to study the electric and optical properties of both annealed and not annealed ITO-covered float glasses, ellipsometry, spectrophotometry, impedance analysis, and X-ray measurements were performed. Moreover, variable angle spectroscopic ellipsometry provides relevant information on the electronic and optical properties of the samples. ITO film is modeled as a dense lower layer and a surface roughness layer. The estimated optical density for ITO and the optical density of the surface roughness ITO layer increases with the annealing temperature. In the near-IR range, the extinction coefficient decreases while the maximum of the absorption in the near UV range shift towards low photon energy as the annealing temperature increases. Spectrophotometry was used to estimate the optical band-gap energy of the samples. The thermal annealing changes strongly the structural and optical properties of ITO thin films, because during the thermal processes, the ITO thin film absorbs oxygen from air. This oxygen absorption decreases the oxygen vacancies therefore the defect densities in the crystalline structure of the ITO thin films also decrease, as confirmed both by ellipsometry and X-ray measurements.

Optical Metamaterials

Metamaterials are artificial composite materials whose extraordinary electromagnetic properties are induced by an appropriate structuring of the medium at scales much smaller than the operational wavelength. For visible light, this "effective medium" requirement implies typical sizes of the artificial structures around a few tens of nanometers or less, hence setting the framework for this research project. The goal of our research project is precisely to fabricate a radically new generation of metamaterials at infrared and optical frequencies, based on the use of nano-chemistry and self-assembly of materials as an alternative, highly innovative fabrication route that clearly veers away from lithography and SRR-type designs. Our main goal is to address and solve the fundamental problem of optical losses in engineered metallic nanostructures. In fact, these materials suffer from rather strong damping of the plasmon fields which can become obstructive for most optical and photonic applications. Therefore, eliminating losses in optical metamaterials is critical for enabling their numerous potential applications. Indeed, metamaterials that use plasmon resonant metal nanoparticles present two distinct problems, each of them reducing the overall transmission through the entire structure namely absorptive ohmic losses, and reflection losses at interfaces. The reflection losses can be suppressed by an optimized design with a matched impedance and/or EM properties gradients whereas the absorptive losses must be compensated with inclusion of active gain media, able to transfer energy to propagating surface-plasmon polaritons (SPPs) and to localized surface plasmons in metal nanostructures using stimulated emission.

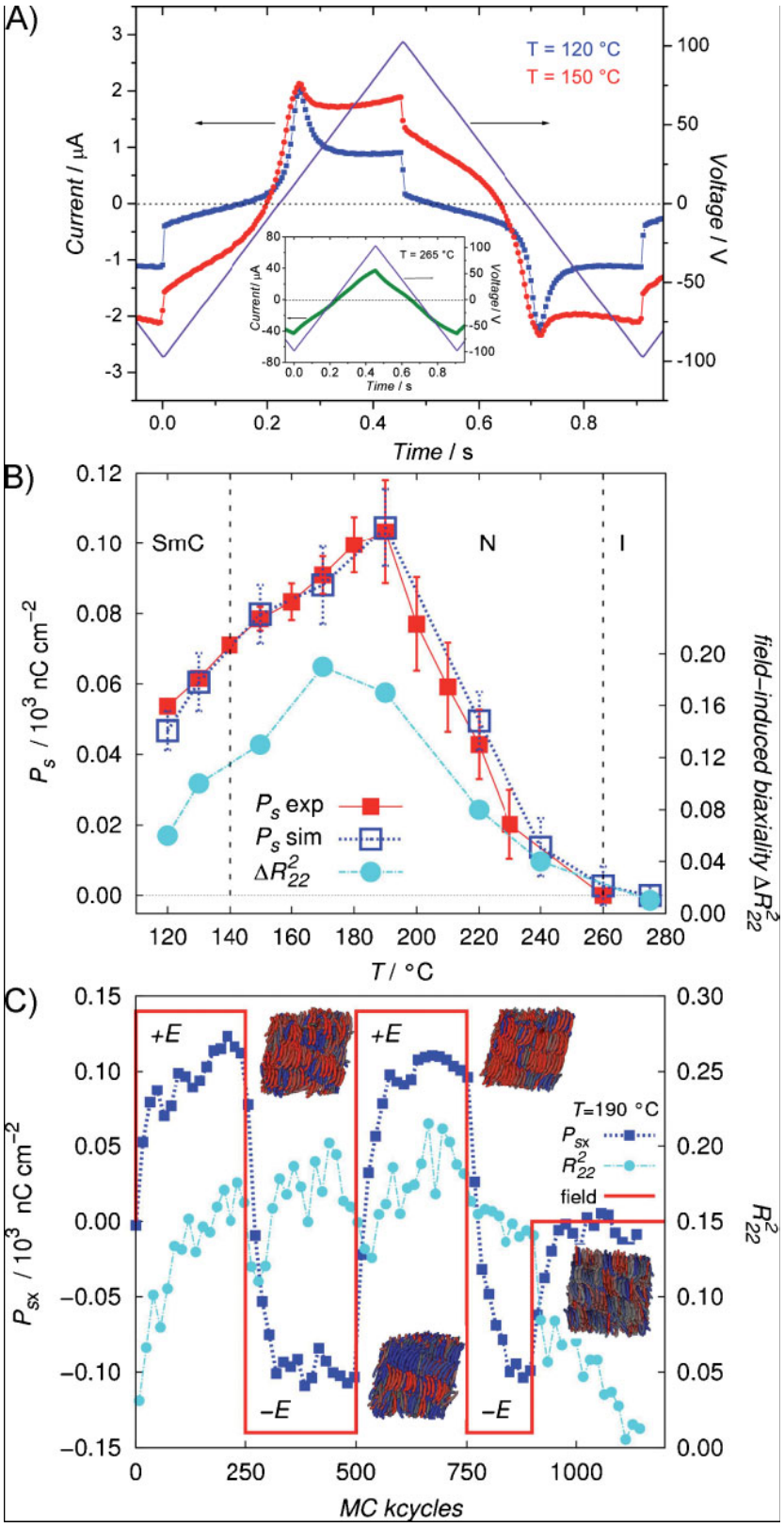
Characterization of rhenium oxide films and their application to liquid crystal cells

Rhenium trioxide exhibits high electronic conductivity, while its open cubic crystal structure allows an appreciable hydrogen intercalation, generating disordered solid phases, with protonic conductivity. Rhenium oxide thin films have been obtained by thermal evaporation of ReO3 powders on different substrates, maintained at different temperatures, and also by reactive magnetron sputtering of a Re metallic target. A comparative investigation has been carried out on these films, by using micro-Raman spectroscopy and x-ray diffraction. Two basic types of solid phases appear to grow in the films: a red metallic H*x*ReO3 compound, with distorted perovskite structures, like in the bulk material, and ordered HReO4 crystals based on tetrahedral perrhenate ions. Because of its conduction properties, the electrical and electro-optical behaviors of ReO3 films deposited on standard indium tin oxide/glass substrate have been tested inside asymmetric nematic liquid crystal cells, showing an appreciable capability of rectification of their electro-optical response, in similar way to tungsten trioxide.

Ferroelectric Response and Induced Biaxiality in the Nematic Phase of a Bent-Core Mesogen

The still undiscovered fluid ferroelectric nematic phase is expected to exhibit a much faster and easier response to an external electric field compared to conventional ferroelectric smectic liquid crystals; therefore, the discovery of

such a phase could open new avenues in electro-optic device technology. Here, experimental evidence of a ferroelectric response to a switching electric field in a low molarmass nematic liquid crystal is reported and connected with field-induced biaxiality. The fluid is made of bent-core polar molecules and is nematic over a range of 120 -C. Combining repolarization current measurements, electro-optical characterizations, X-ray diffraction and computer simulations, ferroelectric switching is demonstrated and it is concluded that the response is due to field-induced reorganization of polar cybotactic groups within the nematic phase. This work represents significant progress toward the realization of ferroelectric fluids that can be aligned at command with a simple electric field.


A)
T = 120 °C
T = 150 °C
Current / μA
Voltage / V
Time / s
T = 265 °C
B)
SmC
N
I
P_s exp
P_s sim
ΔR^2_{22}
P_s / 10^3 nC cm^{-2}
field–induced biaxiality ΔR^2_{22}
T / °C
C)
+E
−E
T=190 °C
P_{sx}
R^2_{22}
field
P_{sx} / 10^3 nC cm^{-2}
R^2_{22}
MC kcycles

7.1.2 Surfaces and interfaces: characterisation, interaction lc-surfaces, polymer surfaces, anchoring, effects on eelctrooptics and photonics

Surface treatment and bulk density of ions in nematic liquid crystals

The frequency dependence of the electrical impedance of a planar nematic sample in the shape of a slab is investigated. The measurements are performed by means of an external voltage of small amplitude _a few tens of millivolts_ in such a manner that the liquid crystal behaves as a linear system from the electrical point of view. In this framework, the nematic orientation induced by the external field is absent because the applied voltage is smaller than the critical one for the transition of Freedericksz for the considered geometry. Our measurements indicate that the real part of the impedance presents a large plateau, finishing at the frequency of Debye. Whereas the imaginary part diverges in the low frequency region, indicating that the electrodes of the cell behave as blocking electrodes. From the value of the plateau of the resistance of the cell and from the frequency of Debye, we can conclude that the surface treatment to orient the nematic liquid crystal has a strong influence on the bulk density of ions. The experimental data relevant to the real and imaginary part of the impedance of the cell have been analyzed with a model based on the equations of continuity for the positive and negative ions and on the equation of Poisson for the actual electrical potential across the sample. By assuming that there is only a type of positive and negative ions and that the electrodes are perfectly blocking, except adsorb ions, we show that the agreement between theoretical predictions and experimental data is good.

The influence of drying temperature on the closed-packed structure of silanized monolayers deposited on indium tin oxide (ITO) substrates

Molecular organization of self-assembled n-dimethyl-n-octadecyl-3- aminopropyltrimethoxysilychloride (DMOAP) layers on ITO coated glass substrates was thoroughly investigated. The layer thickness for each deposition was determined by Variable Angle Spectroscopic Ellipsometry (VASE), while from static contact angle measurements we deduced valuable information regarding the ordering of the molecular structures at solid-air interface. In particular, the DMOAP thin film formation was studied for two different drying temperatures (85°C and 120°C). While at Tdrying=85°C we observed the formation of a molecular monolayer characterized by a closed-packed structure, at the higher temperature the DMOAP molecules 'bend' at the substrate as they stack in relatively disordered clusters. A qualitative interpretation of this phenomenon is given, in good agreement both with the obtained experimental data and experimental investigation reported in scientific literature. The observations regarding the DMOAP molecular level organization in function of substrate temperature could bring essential information to the self assembly research community and also explain some important physical phenomena occurring at interfaces.

Titania Nanostructered Thin Films

Since few year titania mesoporous and titania nanotubes are attracting the interest of a large number of researchers (Journal of Material Chemistry 17(2007)1451-1457) both for energy production (Nano Letters 6(2006)215-218, gas sensors (Thin Solid Films 496(2006)42-48) and for their interesting optical properties (Thin Solid Films 515(2006)2091-2096). Different procedures have been defined to produce ordered TiO2 nanotube layer: by anodization of titanium foils (Journal of Material Science 42(2007)5539-5543, by sol gel synthesis (Macromolecules 41(2008)4551-4554) and by anodization of sputtered Ti films (Advanced Functional Materials 15(2005)1291-1296).

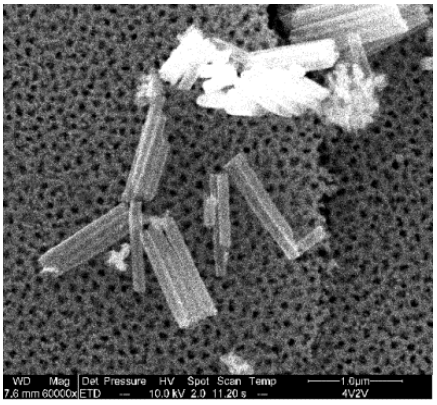


Figure 1

Our laboratory is involved in the study of TiO_2 nanotubes since two years during which a method to produce a homogeneous and transparent film of nanotubes on different type of substrates has been developed. That is the films of TiO2 nanotubes have been obtained by the anodization of titanium layers deposited by DC magnetron sputtering at low partial Ar pressure (~0.03mb). With a target-substrate distance of about 8cm and a sputtering power of 10W/cm^2 a thin (~400nm) titanium coating of the substrate is obtained after 45min. To ensure a good adhesion of the Ti films the substrates are heated at T~400°C during the sputtering process.

The Ti coated substrates are anodized for 180min in the electrolyte solution of NH_4F (0.0035%W) +H_2O (0.0313%W) in Ethylene Glycol by applying a square-wave signal (low level ~ 20V, high level ~120V).
The single walled TiO2 nanotubes layer uniformly cover the substrates, their length can vary from 0.5μm to 1μm and their external/internal diameter is 200nm/100nm (fig 1).

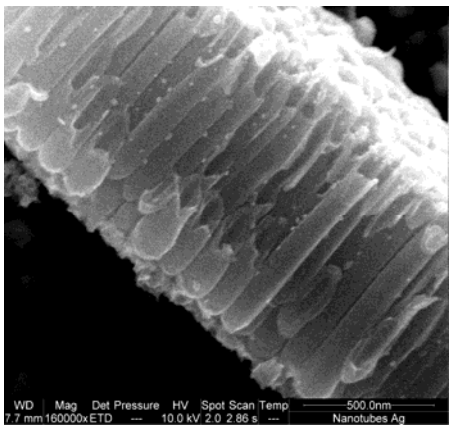


Figure 2

The nanotubes ore opened at one side and can be infiltrated by other substances, i.e. fluids or solids. Figure 2 shows a section view of the TiO_2 nanotubes infiltrated by silver nanoparticles (small white dots).

Nanotube layer are optically transparent and can be isotropic or slightly anisotropic.

Experiments are underway to determine the origin of this anisotropy, also their electrical characteristic are under investigation by spectroscopic ellipsometry and impedance analysis.

Electrohydrodynamic Instabilities in Nematic Liquid Crystals

Anisotropic complex fluids, like e.g. liquid crystals, represent an interesting experimental example of a system exhibiting complex spatiotemporal behavior, a quite common feature in a wide range of systems far from equilibrium.

The early research in pattern formation focused on the presence of simple periodic structures, while the main questions currently addressed concern regimes characterized by higher complexity, that is, patterns that are more irregular in space and time. This is often related to the occurrence of intermediate states between order and turbulence. In particular, electro-hydrodynamic instabilities (EHD) in nematic liquid cristals (NLC) have been widely investigated by electro-optical experimental techniques. The occurrence of EHD is due to the molecular reorientation under the effect of an external electric field. A planar sample of NLC having a negative dielectric anisotropy can be driven through several regimes of increasing stochasticity by tuning the amplitude of the external field, and establishing a sequence of electro-hydrodynamic (EHD) instabilities. These are generated by the competition of two forces: a restoring dielectric torque, owing to the negative dielectric anisotropy, and a force exerted on the bulk fluid due to the charge separation produced by the positive conductivity anisotropy. As result, a recurrent pattern of convective roll structures, associated to the periodic distortion of the director field, n(r), are formed according with the model of Carr-Helfrich [1]. At low electric field's values a simple unidimensional distortion of the molecular field is observed. This regime, named Williams domains (WD), consists in a series of stationary convective rolls with periodicities of the order of the sample thickness. By increasing the amplitude of the electric field the convective cells are longitudinally stretched up to the formation of small scale spatial structures. This regime is indicated as Weak Turbulence (WT). For high values of the applied voltage WT pattern gives raise to the dynamical scattering mode (DSM1). Above a certain threshold of the applied voltage the DSM1 regime becomes metastable and shows a spontaneous transition towards a second DSM mode, this new regime is knows as DSM2. This transition can be explained by a transient bimodalilty process.

Recently we have done the first experimental observation of EHD instabilities in dye doped NLC by confocal fluorescence polarization microscopy Fig 3. This optical technique allows a 3D reconstruction of turbulent patterns with a sub–wavelength resolution and the analysis of the energy clusterization through the entire sample.

Multifractal analysis showed that the energy density were observed to show strong inhomogeneities in their spatial distribution and that the coarse-graining energy density can be characterized by a multifractal distribution . Analyzing , for the first time, what happens to the whole bulk of the NLC sample under the action of an external electric field, we found that the distortion energy is stronger far from the surface, where large-scale structures tends to concentrate due to the low influence of the anchoring energy. Singular structures of the energy density are recovered and important clustering are observed for high values of the external applied voltage V0, when NLC is in a fully developed turbulent state. When this state is reached the whole bulk is influenced by the energy distortion. In this case, the elastic energy concentrates in the center of the sample becomes so stronger to influence the anchoring of the NLC at the boundary glass plates.

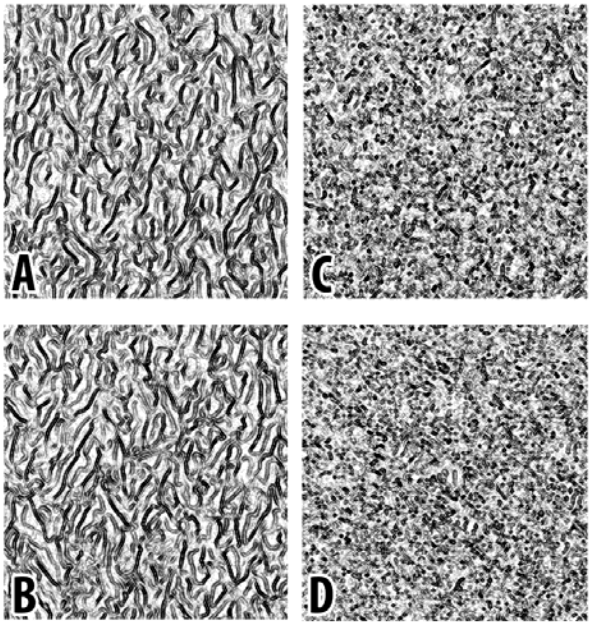


Figure 3

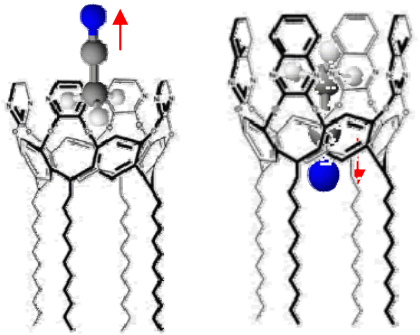
Nonlinear optics characterization of surfaces for chemical sensing and bio-detection.

We explored the opportunities offered by nonlinear optics and, in particular, by the ultrafast sum-frequency generation vibrational spectroscopy (SFG-VS) in the fields of chemical and biochemical sensing. As a second-order nonlinear optical processes, SFG-VS has been proven to be a versatile analytical tool for non-invasive probing of any interface accessible by light, with intrinsic surface specificity, chemical selectivity and sub-monolayer sensitivity. With femtosecond laser pulses in the broadband scheme, it might permit the investigation of ultrafast surface dynamics and chemistry with sub-picosecond time resolution.

We have designed, realized and tested a femtosecond broadband SFG vibrational spectrometer, the first of its kind in Italy. The instrument has been built starting from a Ti:Sapphire laser system and it is now a new facility for surface and interface studies. The SFG-VS apparatus contemporarily provides narrow bandwidth 4ps pulses at 800nm and broad bandwidth 150fs IR pulses (150cm^{-1} FWHM), tunable in the range 2.5-10μm (4000-1000cm^{-1}), for frequency resolved SFG vibrational surface spectroscopy. Beside studying molecular recognition at biomimetic and biological interfaces for sensing applications, it will be also exploited to understand how molecules adsorb and react at interfaces, to elucidate interfacial-driven processes like catalyses, combustions, lubrication, adhesion, wetting, electrochemical reactions and biocompatibility.

The SFG-VS has been used to provide a molecular-level description of surfactant-covered substrates [ie. self-assembly of alkylsiloxane monolayers on fused silica substrates] and their hybrid bimolecular architectures with synthetic chemical receptors [i.e., cavitands]. Molecular conformation and alignment have been deduced for both the surfactant and the synthetic receptor layer, as function of the material composition [i.e., n-octadecylsiloxane (OTS), n,n-dimethyl-n-octadecyl-3-aminopropyltrimethoxysilyl chloride (DMOAP), pyrazine- (PzCav) and quinoxaline-bridged (QxCAv) cavitands] and deposition procedures [i.e., self-assembling, Langmuir-Blodgett, Langmuir-Schaefer].

For the first time ever, molecular-level evidence of the receptor-analyte complexation at the solid-gas interface has been obtained. DMOAP-PzCav and DMOAP-QxCav hybrid bilayers were exposed to vapor of acetonitrile. Unexpectedly, opposite orientation for the complexed analyte molecules has been found depending on the cavity depth.



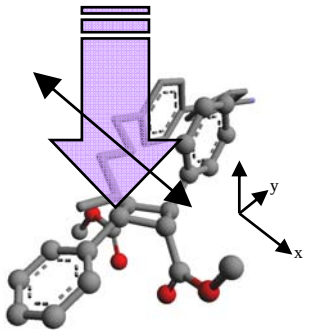
Membrane-mimetic architectures on solid substrates are extremely important for applications that include biosensor devices, preparation of biocompatible surfaces and fundamental studies of membranes. For biosensor applications, solid-supported membranes should contain both phospholipids and membrane receptors in their native conformation, be sufficiently rugged and have an high degree of stability, either in water or in air. Stabilized hybrid bilayer membranes (HBMs) have been obtained by Langmuir-Schaefer deposition of phospholipids on alkylsiloxane SAMs templates. Both OTS-DPPC and DMOAP-DPPC HBMs, supported on planar fused silica substrate, have been investigated by SFG-VS providing a description of their organization and structure.

Reactive polymer surfaces for Liquid crystal alignment

Surface-specific sum-frequency generation vibrational spectroscopy (SFG-VS) is a unique technique that can yield vibrational spectra that are directly related to interfaces and surfaces structure. We have used it to study the photo-induced surface structural change of polyvinyl cinnamate (PVCi), which has been considered a potential polymeric material for photo-alignment of LC in real device applications.

It has been demonstrated that PVCi (and its derivatives) coated substrates after linearly polarized UV irradiation can homogeneously align an LC film in the direction perpendicular to the linear polarization. The orientation of the cinnamate side chains is believed to be responsible for the induced LC alignment. There exist, however, two proposed surface molecular structures of PVCi (and derivatives) induced by irradiation. One is photo-induced dimerization and the other trans-cis isomerization of the cinnamate side chains.

We have investigated UV-irradiated PVCi surfaces, both rubbed and unrubbed, using SFG-VS to determine their surface structural changes. The vibrational spectra of dimerized and undimerized cinnamate chains are different and their input/output polarization dependence yields information about orientations of selected moieties. Our SFG-VS results indicate that polarized UV irradiation dimerizes rather than isomerizes the protruding cinnamoyl side chains at the surfaces and creates significant surface structural anisotropy needed in many applications. Azimuthal anchoring energy measurements of a nematic liquid crystal film on PVCi irradiated by low UV dosages yield results in good correlation with the observed spectral anisotropy.



Electrostatic force microscopy analysis of thin layers of bent-core molecules

Liquid crystals are used in several optoelectronic applications due to their unique properties of self-organization in supramolecular structures. These properties are linked to their molecular shape (rodlike or disk-shaped) and their phase nature (nematic, smectic, or columnar phases). In recent years the possibility to use bent-core liquid crystals for organic molecular devices has been increasingly considered. Bent-core molecules exhibit interesting selfassembling properties due to their special shape. Such molecules pack forming lamellar structures with an in-layer polar order, that gives the overall structure peculiar physical properties such as ferro- or antiferroelectricity.

Since organic molecular devices usually have a thin-film configuration, studies of bent core molecular ordering, morphology and stability at room and elevated temperatures are essential for practical applications. Several efforts have been made in the study of LB thin films but this deposition technique, even if necessary for the understanding of the fundamental packing mechanisms of bent core molecules, is difficult to be implemented in devices production.

Our research aims to study the structure, phase transition and ferroelectric switching of spin cast films of bent core molecules, provided by the Organic Chemistry Department at University of Zaragoza (Spain), at the sub micrometric scale using Atomic Force Microscopy, Electrostatic Force Microscopy and X-Rays reflectometry.

Dynamics of the nematic order

Over the last years, research in nematic electro-optics has been greatly stimulated by the demonstration that biaxial order reconstruction in nematics supports fast coherent switching between two topologically distinct textures. Thermotropic nematics consist of rigid molecular core units, which are usually represented by physicists as simple rods, characterized by cylindrical symmetry. These ideal calamitic units can be used to build a nematic phase with uniaxial order. For this reason, nematic materials are usually described by the scalar order parameter S and the director $\mathbf{n}$, with $\mathbf{n}$ indicating the average molecular orientation and S the degree of scalar order. Nevertheless, under strong external constraints, uniaxial nematics can induce a local and/or transient biaxial order at the nanometric scale, making the ($\mathbf{n}$,S) description inadequate, and requiring a full Q-tensor description of the nematic material. The most important phenomenon that can be investigated with this approach is the "biaxial order reconstruction". This effect depends on ξ_b, the nematic biaxial coherence length and can connect two nematic textures of distinct topologies and optical properties. We are developing methods to control ξ_b, as a promising way to obtain novel electro-optical materials with defined characteristics for electro-optical and/or photonics applications.

In this frame, we have also developed an improved bi-dimensional numerical model using the Q-tensor description that gives good agreement with experimental data. We now solve bi-dimensional cases, adding to the elastic energy expressed with the Landau-de Gennes-Khalatnikov Q-representation method, the third order terms in the Landau

representation to remove the degeneracy between splay and bend elastic constants. Moreover, the temperature dependence of the coefficients of the elastic constants expressions is taken into account and the scalar order parameter is evaluated by calculating the minimum of the Landau-de Gennes potential. The model well reproduces the reconstruction order dynamics and forecast the role of inhomogeneous surface treatment observed experimentally.

7.2 CONFINED SYSTEMS, NANOSCIENCES, PHOTONICS: LASING, GRATING, MEMORIES, HOLOGRAPHY, POLYCRIPS, SOLITONS

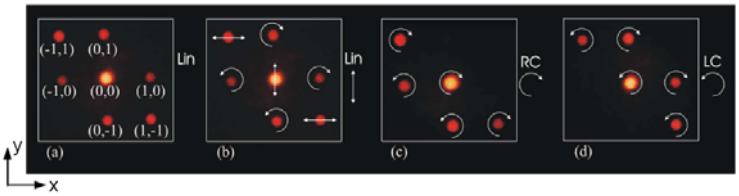
Random Lasing and Metamaterials.

A scientific team of Licryl Laboratory discovered a very intriguing effect regarding random laser action in dye doped complex fluids (nematic liquid crystals) in several confinement geometries and in freely suspended films. This project concerns the investigation of ordered and disordered soft nano-structures to achieve compact, tunable mirror-less laser sources operating in the visible and near-IR regions. The most exciting aspect of these confined systems is that optical and geometrical parameters can be modified by applying weak external fields (e.g., temperature, electric field, mechanical stress), therefore resulting in a direct control of the lasing features (wavelength tunability, bandwidth, emission direction). A multi-pronged strategy has been used to achieve lasing in partially ordered materials such as quasi-crystals, by incorporating fluorescent nano-colloids with fascinating properties. These artificially engineered composites, namely "metamaterials", exhibit a negative refractive index that can present unparalleled opportunities, both scientifically and technologically, making them excellent candidates for developing active reconfigurable optical devices. The survival of coherence effects in multiple scattering has been invoked as responsible for the optical feedback needed for amplification of stimulated emission. Investigations and modelling are currently in progress to gain further understandings on this effect that might lead to new photonic chip architectures and devices, such as zero-threshold micro-lasers, phased arrays and discrete cavity solitons.

Polarization holography in molecular materials

The polarization gratings are generally described as periodic profiles of spatially varying optical anisotropies (linear and/or circular) in photosensitive materials. Differently to the conventional phase or amplitude gratings, they operate by locally modifying the polarization state of light waves passing through them, enabling the development of devices able to control the beam propagation and the polarization state, useful for holographic data-storage, highly functionalized optical devices and display technology. Polarization gratings in polymers, liquid crystals (LC), and LC-polymers composite materials have been widely investigated because of their peculiar diffraction properties, which open the way to promising application in displays and photonic technologies.

1D and 2D LC gratings, obtained by means of different assembling of polarization holograms recorded on photo-aligning substrates, have been investigated. 1D grating has been demonstrated to reach near-100% efficiency, even in the thin-grating configuration, and have been proposed for effective tunable color filter. The 2D gratings diffract light in different directions with different polarization states, that can be optically controlled. Orthogonal circularly and linearly polarized diffraction orders are simultaneously obtained by irradiating the grating with a linearly polarized beam. In both cases, an external ac voltage allows to completely control the diffracted energy distribution and their spectral component.



Polarization grating recording in an amorphous and non-chiral azo copolymer has been investigated. The reported studies show that after illumination with proper polarized light pattern the amorphous polymeric film undergoes a light-guided inhomogeneous supramolecular modification acquiring new functionalities. In the linearly polarized region of the light pattern a linear photoinduced birefringence occurs, while in the region circularly polarized the light guided supramolecular chiral structures result in a circular birefringence. The photoinduced structures strongly affect the polarization state of the light propagating in it, and their optical characterization enables to measure the photoinduced linear and circular birefringence. The recorded gratings show the long-time stability and the full reconfigurability, functional to the multiple holographic recording.

Supramolecular structuring in photosensitive organic materials

In the frame of the PRIN project "Synthesis and Functional Characterization of Photo-active Organic Semiconductors" we have studied the possibility of improving the photoconduction and photorefractivity of several organic polymeric materials through the light induced supramolecular organization. Indeed, it is well known that the

intermolecular interactions that induce the superstructural organization allow the optimum exploitation of the properties of molecular materials. In particular, the activities planned include the following:

- Studies of the photoconductivity in the chiral media by standard techniques, and the influence of light ellipticity and handedness.
- Control of the supramolecular organization of the chiral structure using light and its influence on transport properties.

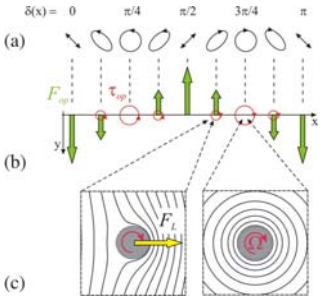
The light induced control of chirality will be performed by exploiting the photochromic functionalities and their interactions with linearly/ elliptically/circularly polarized light.

Optical trapping and manipulation

The field of optical tweezers has grown tremendously in the last years. New techniques that use forces and torques exerted by carefully sculpted light beams improved the level of access and control needed to look at new opportunities of fundamental and applied research in several branches of science.

Although very sophisticated methods to develop multiple and multifunctional optical traps have been proposed, which are able to control the rotation and orientation of particles exploiting the polarization of the light, the intensity gradient is at the basis of their conventional trapping operation principle and none of them make evidence of optical force gradients based on the vectorial nature of the light.

We have demonstrated how a polarization gradient, created via vectorial holography, offers new capabilities for optical trapping and manipulation.



(a) Scheme of the polarization pattern.

(b) The optical torque τ_{op} and the y-component of the optical force F_{op} felt by a spherical particle with diameter lower than the half spatial periodicity of the polarization pattern.

We have studied the manipulation possibilities offered by optical holography and, in particular by light polarization patterns, on micron-sized droplets of LC with radial(optically isotropic) and bipolar (optically anisotropic) configurations. We have widely investigated the polarization patterns obtained by the interference of orthogonally polarized laser beams, in particular s- and p-polarized and opposite circularly polarized beams, and the opportunity they offer to exert both optical forces and torques simultaneously. Interesting optical manipulation features for isotropic particles emerge, as well as an unusual hydrodynamic trapping (i.e., lift, F_L) force for birefringent spinning particles. Indeed, unconventional trapping of spinning particles in circularly polarized fringes has been observed, which suggests the involvement of hydrodynamic forces.

An optical technique developed for sorting of polydisperse microparticles has been used as optical sieve for birefringent spherical particles, i.e. LC droplets. The method is based on the response of the LC droplets to an interference pattern obtained by the superposition of two linearly polarized laser beams. Moving the intensity pattern it is possible to select particles with the same size. The size selectivity depends on the spatial periodicity of the fringes, where the droplets are trapped. Changing the polarization state of the interference beams from linear to circular parallel, trapping and rotation of the droplets in the fringes are observed. A pump-probe technique has been used to measure the rotation frequency of the birefringent droplets.

Laser Action in Liquid Crystals: From Random to Periodic

Extensive studies on one-dimensional (1D) PBG materials have been performed. The birefringence and natural ability to form periodic structures make cholesteric liquid crystalline (chiral nematic) materials particularly attractive as 1D PBG systems. In fact, chiral liquid crystals (CLC) possess a helical superstructure that provides a 1D spatial modulation of the refractive index, giving rise to Bragg selective reflection for circularly polarized light having the same handedness as the LC structure. If a CLC is doped with dye fluorescent molecules, in such a way that the maximum peak of fluorescence matches one of the edges of the selective stop band, the spontaneous emission is suppressed within the bandgap and enhanced at the band edges. At this spectral position the photon

group velocity approaches zero and low threshold mirror-less laser action is expected. By confining the helical super-structure of chiral liquid crystals in polymeric micro-cavity channels a tunable microcavity laser array was achieved.

In random systems, on the other hand, the propagation of the light waves is quite different, as optical scattering may induce a phase transition in the photon transport behaviour. For very weak scattering, the propagation can be described as a normal diffusion process. With an increase of the scattering intensity, recurrent light scattering events arise and the interference between the counter-propagating waves leads to enhanced backscattering, namely weak localization of light. Beyond a critical scattering level, the system makes a transition into a strongly localized state and light transmission is inhibited. This effect can be used as a photon trapping mechanism to obtain laser action in partially ordered and random systems. In the presence of a gain medium, recurrent multiple scattering and amplification substitute for the distributed optical feedback of a regular laser cavity. Due to a random walk with optical gain inside these systems, diffusive lasing action is encountered. Random lasing modes come from the eigenstates of disordered systems and open a particular chapter in the study of the interplay between localization and amplification.

Here, experiments performed on systems having different order degree and confinement are presented and possible technological implications are discussed.

Tunable Micro-Lasers

Cholesteric liquid crystals (CLC) posses a self-organized supramolecular helicoidal periodic structure in which periodicity can be set from 100nm to infinity and which are also characterised by 100% selective reflection of circularly polarized light. When a photoluminescent dye is hosted in a CLC matrix which has been prepared using nematic liquid crystals and chiral dopants, the dye acts as an active material in a resonator. Laser emission can therefore be obtained from the mixture when it is illuminated with a pump laser. The possibility to modify the helical pitch and then the photonic band gap structure of CLCs is an area of extensive study at LiCryL, leading to the identification of new methods for obtaining tunable lasers.

The most recent studies in this field are devoted to the use of specially prepared materials: fluorene derivatives. At present, dye doped cholesteric liquid crystal lasers contain at least three compounds: a nematic material, an optical active dopant and a luminescent dye, that have to be carefully selected according to their optical, solubility, transparency and thermal stability properties. We are using fluorine-based materials, that can act at the same time as chirality promoters and luminescent compounds, to obtain a finely tunable laser emission.

Another advance is the possibility to obtain laser emission from alternative liquid crystalline phases is currently under investigation. Liquid crystalline Blue Phases (BP), that appear in short pitch cholesterics, have self-assembled three-dimensional cubic structures. They are optically active, non-birefringent, and show Bragg reflection of light in the visible wavelength. The application of an electric field produces a versatile effect on the blue phases. It can cause a distortion of the cubic lattice resulting in a shift of the Bragg peaks, in hydrodynamic instabilities, in birefringence changings and in inducing novel phases and phase transitions. We are working to demonstrate that lasing in the blue phases may be tuned and easily controlled by an electric field and/or temperature and therefore be useful for photonic material based devices.

Investigation and Applications of POLICRYPS Gratings

POLICRYPS is a structure made of perfectly aligned liquid crystal films separated by slices of almost pure polymer. Under suitable experimental and geometrical conditions, the structure is obtained by curing a homogeneous syrup of liquid crystal, monomer and curing agent molecules with a spatially modulated pattern of UV radiation. From an optical point of view, POLICRYPS is a holographic diffraction grating with a spatial periodicity that can be easily made of sub-micrometric scale, exhibiting diffraction efficiency values as high as 98%. Depending on the used substrate, the POLICRYPS grating can be utilized both in transmission or reflection, with negligible scattering losses, and can be switched ON and OFF by application of an external electric field of the order of few V/μm. Concerning this structure, in the period of observation (2008), our interest has been devoted to the following arguments:

a) POLICRYPS gratings as switchable phase modulators

POLICRYPS gratings can be used as well as electrically controlled optical phase modulators. Arbitrarily polarized light normally incident on the structure experiences a birefringence that depends on the anisotropy of the composite liquid crystalline material and on the geometrical cell parameters. The sample behaves as a retardation plate in good agreement with the Jones matrix formalism. The birefringence of the modulator can also be tuned by applying a suitable voltage, while a negligible birefringence variation is detected by increasing the incidence power. This makes POLICRYPS structures suitable as switchable phase retarders for high power laser beams.

b) All-Optical switching in (1-2)D structures

We investigate high quality azo-POLICRYPS diffraction gratings to be used for fast all-optical switching in the visible range. The polymeric microstructures, produced in a multistep chemico-physical process, confine and stabilize a well aligned nematic liquid crystal (NLC) film, which is doped with a high performance mesogenic azobenzene dye, sensitive in the visible range. The all-optical switching of the grating between highly diffractive and transparent states is realized by a photochemical phase transition between nematic and isotropic phases based on the photoisomerization of

azobenzene guest molecules. The effect, which is reversible and repeatable, is triggered by a visible pump irradiation and detected through the change in the diffraction efficiency of a low power probe light. Performances of the new structures are highlighted by investigating also the correlation between switching times and pump power.

A Novel Polymer Matrix for Confinement and Alignment of Self-Organized Materials

We report about the realization and characterization of a novel polymer matrix sculptured in photosensitive material devoted to micro/nano-confinement to stabilize a wide range of organic and biological components with self-arrangement properties at the nanoscale. The high quality morphology of a 2D polymer structure is obtained by combining a nano-precision level optical holographic setup and a multi-step chemical-physical process. The sharp and uniform morphology can be conveniently used as templates to be filled with high-refractive index materials or different soft composite elements. Due to their ability as self organization materials, short pitch cholesterics LC, azo dyes LC and ferroelectrics LC have been used. Various experimental studies have been carried out in order to investigate the efficiency of such structures for the realization of electro-optical and all-optical devices. Biological materials and DNA are currently under investigation.

Modeling of Lasing Phenomena

Phenomena associated to lasing in random or quasi-random media are of growing interest both from theoretical and experimental points of view. Recent studies show that nematic liquid crystals are good candidates as scattering host for these lasing systems. A theoretical analysis and Monte Carlo simulations have been performed for different modellizations of scattering in nematics coupled with a two-level system which describes the dye action. A simple description of light diffusion in nematics is inadequate to describe the localization process that is at the basis of the laser action; therefore, different physical phenomena have to be taken into account.

Study of Shock Waves in Liquid Crystals

Shock waves are a general phenomenon thoroughly investigated in disparate area of physics like fluids and water waves, plasma physics, gas dynamics, sound propagation, physics of explosions, etc. They are also expected in (non-hyperbolic) universal models for dispersive nonlinear media, such as the Korteweg-De Vries (KdV) and nonlinear Schrodinger (NLS, or analogous Gross-Pitaevskii) equations. We investigate this phenomenon in a nematic liquid crystal with twofold points of view: numerical and experimental. Numerically we investigate the formation of typical shock profile in space and time solving the Spatial Maxwell wave equation (typical Non linear Schrodinger equation) coupled with the Frank equation (that contain the time evolution). Experimentally we consider the conditions of numerical simulation (liquid crystal alignment, light power, spot size of light beam) in order to reproduce the shocks waves in nematic liquid crystal.

Electro-optical response due to mixed conduction electrodes, compared to ferroelectric ones, in asymmetric nematic liquid crystal cells

The usual liquid crystal cells show an electrooptical response symmetric to the applied voltage. On the contrary, when mixed conduction films such as tungsten trioxide or vanadium pentoxide are inserted on one side of the cell, the electro-optical response is asymmetric with respect to the applied voltage. Depending on the structural phase of the inserted film the electro-optical response is in phase (transmission ON during the anodic polarization on metal oxide electrode, transmission OFF during the cathodic one) or in opposition of phase (reverse combination). The first case has been explained by the formation of a double charge layer at the interface metal oxide–liquid crystal, because of migration of protons contained in the oxide films. The other case has been found after high temperature treatments of metal oxides deposited on glass–ITO substrates, and it appears quite similar to the response collected by using films of ferroelectric materials such as lead zirconium titanate (PZT). This fact suggests a possible interpretation in terms of dielectric response, when the mixed conduction films undergo high-temperature treatments. A comparative study of films of WO3, V2O5, and PZT is carried out in this work as a function of the annealing temperature.

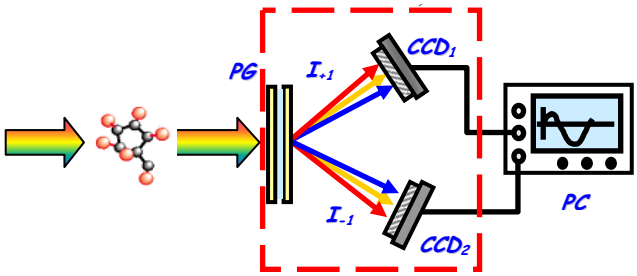
7.3 APPLICATIONS: SPECTROMETERS, SENSORS, DEPOLARIZING SYSTEMS, EHD, LCD, CD

Chiro-optical spectrographs for real-time and artefacts-free measurements

Many chiro-optical methods have been proposed to investigate the structure of optically active molecules. Optical rotation, optical rotatory dispersion, circular dichroism, and circularly polarized emission or luminescence are extremely sensitive probes and the observables associated with these phenomena may be directly related to the parameters characteristic of the structural details, both in the molecular ground states and in the excited states.

On the basis of these phenomena several techniques have been developed as the Circular Dichroism (CD), Circularly Polarized Luminescence (CPL), Vibrational Circular Dichroism (VCD) and Raman Optical Activity (ROA) spectroscopic techniques.

Novel and simple diffractive spectrographic methods for measurements of CD, CPL and ROA have been considered from both a theoretical and experimental approach, which simplify the instrumental design, reduce the artefacts and enables simultaneous detection of the chirooptical spectra in the range of interest. The main element of the devices is a polarization holographic grating, recorded in a thin photosensitive organic film, by two interfering opposite circularly polarized beams. A peculiarity of this grating is that the amplitude of the +1 (-1) order of diffraction is proportional to the right (left) circular polarization component of the incoming beam. A demonstrator prototype of the CD spectrograph has been developed and its performance has been compared with a commercial phase-modulation CD spectrograph. We have demonstrated that the CD spectrum of a specimen can be easily evaluated from the intensities of the diffracted beams. Due to the spectral selectivity of the grating, the CD at each wavelength can be evaluated at the same time using two linear array detectors. In case of general anisotropic samples (i.e., films of proteins), showing both linear and circular anisotropies (birefringence and dichroism), the adoption of unpolarized white light with the proposed device allows for artefacts-free measurement of the *true*-CD spectrum.



Theory of Polarized Light Beam and Depolarizing Media

Coherence phenomena in optics attract more and more attention as a fundamental point of view and for their increasing importance in the technology (e.g. optical signal transmission and processing of information, optical reflectivity of diffusive biological tissues, etc.).

.In order to describe the overall polarization of a light beam having a non-uniform distribution of the polarization and of the intensity over the light beam cross section, we have generalized the expression of the Stokes parameters calculating their averages over the beam transverse cross-section. We have applied our formalism to the description of the simple case of a cross section divided in only two parts with different polarization states. The experimental observation performed on a nematic liquid crystal cell confirm our theory providing the correct behaviour of the Stokes parameters, in particular the beam looks totally depolarized as long as it is constituted by two regions with both equal intensity and orthogonal polarization states. Then we have consider the most complex model consisting in a cross section divided in N regions: we assumed that the polarization of every regions is well defined, while there is no correlation between the polarization states of different regions. This model can also be apply to the superposition of N totally incoherent waves with different polarizations and intensities.

The principal result of this model is that the degree of polarization P of the light beam is inversely proportional to the square root of N, $P=(1/N)^{0.5}$, hence the degree of polarization gives the number of waves in a light beam with uncorrelated polarization states and which are incoherent. Moreover P is a measure of the number of spatially separated parts of a cross section that have uncorrelated polarization. We have introduced the correlation function between two different polarized regions of the cross section and another function that is the analogous of the visibility function in interference processes, and we have shown how degree of polarization depends on these functions.

This model opens a scenario of new possible investigations. For example we can study how chaotic or disorder birefractive samples could modifies the light polarization, it has been applied to the study phase transitions and pattern formation in liquid crystals measuring the time behaviour of the Stokes parameters to follow the dynamic of these systems . Moreover one possibly important connection should be made with the theory of spatial variation of polarization (linear versus circular) in monochromatic beam, where the degree of linear polarization is function of position.

Realization and characterization of photonic aperiodic structures with a photo-polymerization technique.

These structures are realized using a novel approach to their fabrication based on the use of a programmable Spatial Light Modulator encoding Computer-Generated Holograms. This approach will also possibly allow (by comparison) a further understanding on the diffusion process driving the holographic realization of periodic structures such as diffraction gratings.

7.5. NANO-IMAGING OF BIOLOGICAL AND BIOCOMPATIBLE MATERIALS AND SURFACE FORCE APPARATUS (SFA)

Nano-imaging of biological materials

Advanced microscopy techniques, such as Atomic Force Microscopy (AFM) and Environmental Scanning Electron Microscopy (ESEM), are finding application in biology and biomedical investigations since they are non-destructive techniques and can be performed in liquid-humid environments.

Using AFM in liquid, we have studied the mechanical properties of intraocular lenses, used for cataract surgery, as well as their topographical features. Bacterial adhesion to intraocular lenses during the implantation in the human

body is the main cause of endhophthalmitis. We believe that a better knowledge of the biomaterial adhesive properties, on micro and nano scale, can lead to a better understanding of the adhesion mechanisms of bacteria on lenses.

AFM and ESEM are currently used to investigate the aggregation properties of proteins such as □-lactoglobulin as influenced by the presence of a substrate. This protein is used as a "model-protein" to study the different types of aggregation that can occur i.e. globular aggregates or fibrils formation. In particular the understanding of the mechanism of fibrils formation is important since it is related to several medical diseases (Alzheimer, Parkinson).

AFM and phase imaging on membranes and block copolymers

AFM is used to provide a better insight in the topographical properties, on a scale not accessible to ESEM, of membranes developed at the Department of Chemical, Engineering and Materials (UNICAL).

The chemical engineering group is developing membranes with ordered features made by block copolymers PS-PB (polystyrene and polybutadiene) changing the production conditions. The membranes are investigated in Tapping Mode AFM and information about the mechanical properties of the membranes are obtained monitoring the first harmonic signal. A device to easily extract the phase signal from a commercial AFM (Veeco Instruments) is currently under development.

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   Realization process of a polymer matrix formed by polymeric slices, carved by using a photo polymerization process, alternated with empty channels
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A PUBLICATIONS ON SCIENTIFIC JOURNALS
A.1 Publications on international journals
A.1.1 Publications on international journals printed in 2009

1. C.Y. Chen, W.T. Liu, P. Pagliusi, Y.R. Shen,
   Sum-Frequency Vibrational Spectroscopy Study of Photoirradiated Polymer Surface,
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3. Ferjani, S; De Luca, A; Barna, V; Versace, C; Strangi, G,
   Thermo-recurrent nematic random laser,
   Optics Express 17 (3):2042-2047 2009

4. Castriota, M; Marino, S; Strangi, G; Versace, C; Scaramuzza, N; Cazzanelli, E,
   Electro-optical response due to mixed conduction electrodes, compared to ferroelectric ones, in asymmetric nematic liquid crystal cells,
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5. D'Elia, S; Scaramuzza, N; Ciuchi, F; Versace, C; Strangi, G; Bartolino, R,
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19. M. Castriota, S. Marino, G. Strangi, C. Versace, N. Scaramuzza and E. Cazzanelli,
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Ionics **15**, pp139-149 (2009); **IF 0,563**

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Journal of Material Research 24, pp.475-481 (2009), IF 2,178

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Journal of Applied Physics 105, 1 , pp. 1-7 (2009) ; IF 2,479

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Anomalous enhancement of Raman scattering of metal oxide films deposited on thermally treated ITO-coated glass substrates
Chemical Physics Letters, 478, pp. 195-199 (2009); IF 2,341

23. O. Francescangeli, V. Stanic, S.I. Torgova, A. Strigazzi, N. Scaramuzza, C. Ferrero, I.P. Dolbnya, T.M. Weiss, R. Berardi, L. Muccioli, S. Orlandi, and C. Zannoni,

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A.1.2 Publications on international journals accepted in 2009

1. Mazzulla, C. Provenzano, P. Pagliusi, G. Cipparrone,
Real-Time Circular Dichroism Spectrograph Based on a Single Liquid Crystal Diffractive Element,
Molecular Crystals and Liquid Crystals.

2. Rizzuti B, Zappone B, De Santo MP, Guzzi R
Native beta-Lactoglobulin Self-Assembles into a Hexagonal Columnar Phase on a Solid Surface,
Langmuir.

3. Buonomenna MG, Golemme G, De Santo MP, Drioli E,
Direct Oxidation of Cyclohexene with Inert Polymeric Membrane Reactor,
Organic Process Research & Development.

4. De Santo MP, Matranga MA, Ciuchi F, Petriashvili G, Barberi R,
Lasing Stability Enhancement in Dye Doped Cholesteric Liquid Crystals,
Molecular Crystals and Liquid Crystals.

5. H. Ayeb, G. Lombardo, A. Gharbi, G. Durand, R. Barberi,
Anchoring breaking or surface order reconstruction in nematics,
Applied Physics Letters.

6. L.S. Chinelatto Jr; J. del Barrio; M. Pinol; L. Oriol, M. Ariosto Matranga, M. P. de Santo, R. Barberi,
Oligofluorene blue emitters for cholesteric liquid crystal lasers
Journal of Photochemistry and Photobiology A.

7. R. Caputo, I. Trebisacce, L. De Sio, C. Umeton,
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Optics Express.

8. L. De Sio, A. De Luca, G. Liveri, C. Umeton,
Observation of hysteresis effects in POLICRYPS holographic gratings,
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9. L. De Sio, S. Serak , N. Tabiryan, S. Ferjani, A. Veltri, C. Umeton,
Composite holographic gratings containing light responsive liquid crystals for visible bichromatic switching,
Advanced Materials.

10. D. Donisi, R. Asquini, A. d'Alessandro, B. Bellini, R. Beccherelli, L. De Sio, C. Umeton,
Integration and Characterization of LC/Polymer Gratings on Glass and Silicon Platform,
Molecular Crystals Liquid Crystals.

11. N. Coppedè, M. Castriota, E. Cazzanelli, S. Forti, G. Tarabella, T. Toccoli, K. Walzer and S. Iannotta;
Controlled Polymorphism in Titanyl Phthalocyanine on mica by Hyperthermal Beams : a Micro-Raman analysis,
Journal of Physical Chemistry C.

12. N. Scaramuzza, M. Castriota, S. D’Elia, S. Marino, E. Cazzanelli, C. Versace and R. Bartolino,
Thermal induced changes of Lead Zirconium Titanate films and their consequences for liquid crystal devices applications,
Philosophical Magazine.

13. E. Bruno, F. Ciuchi, M. Castriota, S. Marino, G. Nicastro, E. Cazzanelli and N. Scaramuzza, *Structural Transformations of PZT 53/47 Sol-Gel Films Driven By Thermal Treatments,* Ferroelectrics.

14. A. Th. Ionescu, A. L. Alexe-Ionescu, S. Marino, M. Castriota, G. Strangi and N. Scaramuzza, *Study of conductivity on a PZT thin film deposited on a copper substrate electrode,* Philosophical Magazine.

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17. M. Castriota, E. Cazzanelli, D. Pacilè , L. Papagno, C. O. Girit, J. C. Meyer, A. Zettl, M. Giarola and G. Mariotto, *Spatial dependence of observed Raman frequencies and disorder in graphene monolayers*, Diamond & Related Materials 19, pp. 608–613 (2010) IF 2,157

18. R. Barberi and G. Chilaya, *Light Controllable, Frequency Tunable Cholesteric DFB lasers*, in "Liquid Crystal Microlasers", edited by R. Bartolino e L. Blinov, ISBN: 978-81-7895-469-1.

B PUBLICATIONS ON CONFERENCE PROCEEDINGS

B.1 Publications on international conference proceedings in 2009

1. I. Ricardez-Vargas, C. Provenzano, P. Pagliusi, G. Cipparrone, *Optical trapping and manipulation involving liquid crystals and vectorial holography* CLEO/Europe - EQEC 2009 - European Conference on Lasers and Electro-Optics and the European Quantum Electronics Conference, 51946 (2009)

2. P. Pagliusi, C. Provenzano, A. Mazzulla, G. Cipparrone, *Diffractive spectrograph for real time circular dichroism measurements* CLEO/Europe - EQEC 2009 - European Conference on Lasers and Electro-Optics and the European Quantum Electronics Conference, 51962 (2009)

3. P. Pagliusi, C. Provenzano, V. P. Shibaev, G. Cipparrone, *Photoinduced superstructural chirality in photochromic polymer: A viable route to light polarization control* CLEO/Europe - EQEC 2009 - European Conference on Lasers and Electro-Optics and the European Quantum Electronics Conference, 51963 (2009).

C INVITED PRESENTATIONS

C.1 Invited presentations at international conferences in 2008

1. C. Umeton, L. De Sio, S. Serak, N. Tabirian, *All Optical Switching of Holographic Gratings Realized in Composite Materials Containing Photosensitive Liquid Crystals*, 13th Topical Meeting on the Optics of Liquid Crystals- OLC 2009- (Invited talk)

D PRESENTATIONS AT CONFERENCES

D.1 Presentations at international conferences in 2009

1. C. Provenzano, P. Pagliusi, A. Mazzulla, G. Cipparrone, *Diffractive Spectrograph For Real Time Circular Dichroism Measurements* CD-2009 12th International Conference on Circular Dichroism, August 30 – September 2nd (2009), Brescia, Italy.

2. I. Ricardez-Vargas, C. Provenzano, P. Pagliusi, G. Cipparrone, *Optical trapping and manipulation involving liquid crystals and vectorial holography*

CLEO/Europe European Conference on Lasers and Electro-Optics, June 14-19 (2009), Munich, Germany.

3. P. Pagliusi, C. Provenzano, A. Mazzulla, G. Cipparrone,
   Diffractive spectrograph for real time circular dichroism measurements
   CLEO/Europe European Conference on Lasers and Electro-Optics, June 14-19 (2009), Munich, Germany

4. P. Pagliusi, C. Provenzano, V. P. Shibaev, G. Cipparrone,
   Photoinduced superstructural chirality in photochromic polymer: A viable route to light polarization control
   CLEO/Europe European Conference on Lasers and Electro-Optics, June 14-19 (2009), Munich, Germany.

5. I. Ricardez-Vargas, C. Provenzano, P. Pagliusi, G. Cipparrone,
   Vectorial holography: liquid crystals emulsion to explore new strategies of optical manipulation
   OLC-2009 13th Topical Meeting on the Optics of Liquid Crystals, September 28th – October 2nd (2009), Erice (Trapani), Italy.

6. G. Chilaya, G. Petriashvili, A. Chanishvili, R. Barberi, G. Cipparrone, A. Mazzulla, M.P. De Santo, M.A. Matranga
   Frequency tunable single mode lasing in three layer systems consisting of clc and dye solution.
   OLC-2009 13th Topical Meeting on the Optics of Liquid Crystals, September 28th – October 2nd (2009), Erice (Trapani), Italy.

7. I. Ricardez-Vargas, C. Provenzano, P. Pagliusi, G. Cipparrone,
   Manipulation of birefringent liquid crystal droplets via circularly polarized optical sieve
   OLC-2009 13th Topical Meeting on the Optics of Liquid Crystals, September 28th – October 2nd (2009), Erice (Trapani), Italy.

8. C. Provenzano, P. Pagliusi, V. P. Shibaev, G. Cipparrone,
   Light-driven supramolecular chirality in azobenzene polymer for polarization control
   OLC-2009 13th Topical Meeting on the Optics of Liquid Crystals, September 28th – October 2nd (2009), Erice (Trapani), Italy.

9. A. Mazzulla, M.P. De Santo, M.A. Matranga, R. Barberi, G. Cipparrone, G. Petriashvili,
   Holographic gratings in liquid crystalline composite photo-initiated by luminescent dyes
   OLC-2009 13th Topical Meeting on the Optics of Liquid Crystals, September 28th – October 2nd (2009), Erice (Trapani), Italy.

10. L. De Sio, S. Ferjani, G. Strangi, C.P. Umeton, R. Bartolino,
    A novel polymer matrix for confinement and alignment of self-organized organic materials,
    13th Topical Meeting on the Optics of Liquid Crystals - OLC 2009 (Oral presentation).

11. A. Veltri, M. Infusino, G.Strangi, C. Umeton,
    Random lasing in dye doped nematic liquid crystal,
    9th Workshop "Novel Optical Materials and Applications", - NOMA 2009 (Oral presentation).

12. R. Caputo, I. Trebisacce, L. De Sio and C. Umeton,
    Phase modulator behavior of a wedge-shaped POLICRYPS diffraction grating,
    9th Workshop "Novel Optical Materials and Applications" – NOMA 2009 (Poster presentation).

13. N. Coppedè, T. Toccoli, G. Tarabella, S. Forti, M. Nardi, M. Tonezzer, M. Pola, C. Corradi, B. Rossi, E. Cazzanelli, R. Verucchi, S. Iannotta,
    Solid State Solar cells based on Hybrid material synthesis by Supersonic Beam Codeposition,
    XIX Congresso AIV Senigallia, Italy, May 19-21, 2009

14. Castriota M. , Cazzanelli E. , Pacile' D. , Papagno L. , Mariotto G.,
    Spatial dependence of Raman frequencies in ordered and disordered monolayer graphene,
    Contribution to Diamond 2009, Athens (Greece), September 6-10, 2009. Poster

D.2 Presentations at national conferences in 2009

1. Castriota M. , Cazzanelli E. , Coppedè N. , Forti S. , Iannotta S. , Tarabella G. , Toccoli T. , Walzer K. , *Micro-Raman analysis on polymorphism and order control in Titanyl Phthalocyanine thin films grown by Supersonic Molecular Beam Deposition*,
Contributo a XXI Congresso Nazionale GNSR, Milano (Politecnico), 10/02/09 – 13/02/09 2009. Poster

2. Cazzanelli E. , Castriota M. , Pacile' D. , Papagno L. , Mariotto G. ,
Spatial dependence of observed Raman frequencies and disorder in graphene monolayers,
Contribution to the XXI Congresso Nazionale GNSR, Milano (Politecnico), 10/02/09 – 13/02/09 2009. Oral.

OTHER PRESENTATIONS AND EVENTS

- START CUP CALABRIA 2009, Rende, 27/10/2009, -2° Admission to "Business Plan Competition"- for the NOTREDAME project (*"iNnOvative subsTRatEs Development for electro-opticAl polyMeric flexible self consistent devices for applications in the field of the Energy saving"*)

- PREMIO NAZIONALE DELL'INNOVAZIONE, PNI 04/12/2009 PERUGIA, QUALIFICATION AMONG THE FIRST 10 NATIONAL WINNERS, WITH PUBLIC PRESENTATION OF THE PROJECT NOTREDAME, inside the theater Morlacchi, during the final awards ceremony of the "National Business Plan Competition".

- INTESA SANPAOLO START UP INITIATIVE, 25/01-30/01/2010 MILANO, Selected participation to the meeting organized by BANCA INTESA-SANPAOLO, for the NOTREDAME project

- GREEN TECHNOLOGIES INVESTMENT FORUM, 11/02/2010 MILANO, Selected participation to the meeting organized by ASSOCIAZIONE IBAN (ITALIAN BUSINESS ANGELS NETWORK) AND BY SWEDISH BUSINESS REGION GOTEBORG AB, for the NOTREDAME project.

- TECHGARAGE CLEAN & GREEN, 26/03/2010 MILANO, Selected partecipation to the meeting organized by Associazione TechGarage, Politecnico di Milano, *Libera Università Internazionale degli Studi Sociali,* (LUISS) "Guido Carli" and dPixel, for the NOTREDAME project.

8. BIOMEDICAL PHYSICS

Area coordinator: L. Sportelli (*Molecular Biophysics Group*)

Professors and researchers: A. Santaniello (*Professore a contratto of Biomedical Physics*)
R. Guzzi (*University of Calabria, Molecular Biophysics Group*)
V. Carbone (*University of Calabria, Astrophysics Group*)
R. Bartolino (*University of Calabria, Soft Matter Group*)

Post-Doc fellow: A. Vecchio (*University of Calabria, Astrophysics Group*)

Undergraduate students: A. Giorno, I. Bonetti,

Graduate students: G. Sceni (*Master student: Diritto e Management Sanitario, Dipartimento di Scienze Giuridiche*)

Collaborators: G. Barca, R. Siciliano (*Azienda Ospedaliera di Cosenza, U. O. Fisica Sanitaria*)
E. Jorio (*University of Calabria, Dipartimento di Scienze Giuridiche*)

Introduction

The two current research activities in Biomedical Physics concern:

1) dosimetry with novel materials for therapeutic applications at low doses;
2) analysis of complex biomedical data and health systems by means of theoretical approaches and methods.

Dosimetry of fractionate dose administration in radiotherapy motivates the development of new materials which, by offering increased sensitivities, allow the extension of the detection capabilities towards lower doses. New measuring approaches and dosimetric devices based on these new materials are accordingly developed and tested. Electron paramagnetic resonance (EPR) dosimetry is based on the measurement of radioinduced radicals, the standard dosimetric material being alanine. More recent dosimetric devices involve sugars, dithionates and formates, among others. These EPR-sensitive materials can be modified by inclusion of paramagnetic species or isotope substitution to further increase low dose sensitivity below 1 Gy. We were concerned with studies of the EPR signal in Li formate irradiated with clinical photon beam at doses in the therapeutic range. The signal was calibrated, and the effect of impurities and defects was investigated, in view of the subsequent realisation of a prototypal dosimeter.

Modern medicine imaging and biomedical experiments are concerned with the interpretation of large data sets often affected by noise, artefacts and redundancy. Algebraic treatments of the data simplify the interpretation and evidence details which would remain otherwise unrecognized. Within this frame, proper orthogonal decomposition (POD) projects the data onto a basis set derived from the data itself, and responding to an optimality criterion. This procedure evidences specific features of the data, without external assumptions on the data behaviour. We applied proper orthogonal decomposition (POD) to the analysis of cardiac magnetic resonance (CMR) images.

Health systems are complex systems, where several disciplines, techniques and methods merge into a single sanitary activity, and the actions of professionals originating from very different fields are coordinated in a strongly interrelated fashion. The combined study of the technical and managerial features of selected sanitary apparatuses and methodologies, including the analysis of the risks and the failures of the systems, aim to preserve the health of the patient and increase the efficiency of the treatments, while reducing the expenses for the sanitary system and improving satisfaction of the patient and of the medical/nursing staff.

8.1 MODIFICATIONS INDUCED BY IRRADIATION OF MATERIALS FOR RADIATION DOSIMETRY

Lithium formate monohydrate ($HCO_2Li{\cdot}H_2O$) was irradiated with photon beams from a LINAC accelerator at energies of several MeV in the dose interval 0.5–80 Gy with variable dose rates in the therapeutic range (of the order of several 10^{-2} Gy/min). The irradiations were performed in collaboration with R. Siciliano and G. Barca of the AO of Cosenza. The number of stable radicals induced by irradiation at g = 2.0053 is suitable for dosimetric purposes, by determining the EPR response as a function of the dose. The calibration curve thus obtained was determined, and checked as a function of the dose rate at the Molecular Biophysics Laboratory by R. Guzzi in collaboration with A. Santaniello. The influence of the preparation and/or environmental conditions on the pristine salt showed up in an increased signal of the so-called second radical species, with respect to literature data. Investigation of $HCO_2Li{\cdot}H_2O$

modified by inclusion of paramagnetic species was planned and is under way. This work was discussed in a thesis ("Dosimetria a basse dosi con materiali innovativi", Ilaria Bonetti, laurea triennale 30.09.09, relatori: A. Santaniello, R. Guzzi, R. Siciliano), and a paper is in preparation for publication.

8.2 TRANSFER TO MEDICINE OF THEORETICAL MODELS AND METHODS

8.2.1 Application of algebraic methods to biomedical data

Proper Orthogonal Decomposition as a diagnostic technique in urology and cardiology

The investigation of the spatial and temporal evolution of renal scintigraphies by Proper Orthogonal Decomposition allowed the detection of abnormal features in renal morphology or renal function, leading to objective and independent criteria of analysis, beyond naked eye inspection. Images of the radiation emitted by a radiopharmaceutical within the kidney were acquired by a gamma-camera, the time behaviour being constructed by a series of snapshots. Each POD mode supplied information about the transit of radiopharmaceutical within the kidney, and in particular on the accumulation and expulsion processes of the radioactive tracer. Results show that the first fundamental mode describes the main properties of captation and expulsion and further eigenfunctions are associated to energetically less relevant phenomena. However, these modes are useful to evidence physiological phenomena that are not captured by the first main mode.

Proper Orthogonal Decomposition was applied to the study of the physiology and the pathology of the left cardiac ventricle, by analysing images of the beating heart obtained by cardiac magnetic resonance. This technique is a special application of magnetic resonance imaging in which the myocardial spatio-temporal evolution during the heart beat is acquired by gating the magnetic resonance signal to the patient electrocardiogram. The POD modes give information on the spatio-temporal features of the healthy or ill myocardium, reflecting functional and dysfunctional behaviours in the contraction-distension cycle. Hence, the first POD mode describes the time-dependent volume variation of the left ventricle, showing reduced systolic or diastolic intervals according to the occurring pathologies. This work was discussed in a thesis ("*Analisi POD di dati di risonanza magnetica cardiaca*", Annamaria Giorno, laurea triennale 16.12.09, relatori A. Santaniello, A. Vecchio), and a paper is in preparation.

Data analysis and modeling of prey-predator systems

The activities concerning the description of the complex dynamics of a predator-prey system by reaction-diffusion equations as described in the previous Activity Report (year 2008) are presently continuing.

8.2.2 Risk analysis and management of health systems

Modern health care is characterised by a large technological content. However, both patients and health professionals are becoming aware that a high technological level carries implications on the quality of the clinical treatment which are not only directly related to the acquisition and management of the apparatuses, but depend also on managerial consideration (number of patients/region, location of the apparatus on the territory). The combined use of positron emission tomography and computer tomography in the so called PET-TC scanner is an example of this. The costs of acquisition and manteinance of a PET-TC by a regional Azienda Ospedaliera are analysed and justified based on managerial and financial considerations, including the availability of the radiofarmaceuticals in relation to both the number of patients and the rate of the examinations, their purchasing costs if not produced in situ, the cost of their disposal over the long period, the costs of the rooms and other facilities dedicated to radioprotection purposes. The acquisition is considered economically sound by comparing the estimated costs/treatment and the number of oncological pathologies for which the PET-TC is diagnostically appropriate assessed in the region. Management aspects in a diagnostical medical context were analysed in the Thesis of the Master in "Diritto e Management Sanitario", Dipartimento di Scienze Giuridiche, supervised by A. Santaniello in collaboration with prof. E. Jorio of the Dipartimento di Scienze Giuridiche and prof. Bartolino of the Soft Matter Group ("*Tomografia ad Emissione di Positroni (PET-TC): aspetti gestionali, diagnostici e implicazioni strategiche di una tecnologia innovativa*", Giuseppe Sceni, Fisico Medico, Responsabile dell'U.O. di Fisica Sanitaria presso l'Azienda Ospedaliera Bianchi-Melacrino-Morelli di Reggio Calabria 19.06.2009, relatori: prof. R. Bartolino, A. Santaniello).

A PUBLICATIONS ON SCIENTIFIC JOURNALS

A.1.2 Publications on international journals accepted in 2009

1. P. Veltri jr., A. Vecchio, V. Carbone,
   Proper Orthogonal Decomposition analysis to investigate the spatial and temporal behavior of renal scintigraphy,
   Physica Medica

A.1.3 Publications on international journals submitted in 2009

1. S. Donato, L. Primavera, A. Vecchio, V. Carbone,
   Complex dynamics of a predator-prey system,
   Chaos, Solitons and Fractals

2. V. Carbone,
   Latency period of infection and absence of CD4+ T cells depletion in a dynamical model of HIV evolution,
   Physica A.

9. GEOPHYSICS

Professors and Researchers: I. Guerra
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G. Neri, B. Orecchio, D. Presti and F. Tafaro (*Univ. of Messina, Messina, Italy*)
D. Costantino *(Polytechnic Univ., Bari, Italy)*
W.J. Kim, A. Lerner-Lam, L. Seeber, C. Stark and M. Steckler (*Lamont-Doherty Observatorv, Columbia Univ., New York, USA*)
V. Carbone, A. Vecchio, P. Veltri, G. Zimbardo *(Calabria Univ., Arcavacata, Italy)*
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RESEARCH LINES

Introduction

The research group is engaged in many lines of activity, in spite of its lean composition. In most cases this is due to the nature of its activities, based on the elaboration of experimental data collected by means of observations that have to be carried on over long span of time. The group indeed was established about thirty years ago in a department different from Physics with the explicit finality of answering the requirement of seismological observations in Calabria, a region characterized by a seismic risk among the highest in the Mediterranean Basin. This origin is still conditioning its programs, mainly of observational nature.

Due to the relatively great distance from the nearest centres of geophysical research and the relevance of the geodynamical problems arising from the features of the territory, the group at the Department of Physics is a reference point for both researchers, from abroad too, as well as some public administrations.

9.1 Seismotectonics

Seismotectonics is the branch of seismology that deals with the complex relations between earthquakes and geological structures and with the reconstruction of the ongoing dynamical processes. It is based on the accurate location of the seismic sources, that in turn requires a model as more realistic as possible for the elastic waves propagation in the studied area. Generally, an iterative process is performed: new seismographic data help to better constrain the velocity model that in turn leads to better locations. The maps of seismicity resulting from the above mentioned activity is then correlated to the tectonic features observed in the area. In particular the space distribution of the seismic foci can trace the position of the slip surfaces at depths not accessible to direct observation, while the propagation model includes the mechanical discontinuities met with by seismic waves along their path to the seismic stations. Seismograms contain further information that allows for determining the dynamics of the phenomena at the seismic sources. The reconstruction of the geometry of the geological bodies and their present kinematics is the result of these research activities.

Accurate seismotectonic investigations are essential in Calabria because of the peculiarity of seismic activity in the region. The area hosted in fact most of the largest earthquakes reported in Italy in historical times. However it had been practically quiescent since 1908. Moreover the adjacent Tyrrhenian Sea is the seat of deep earthquakes attributable to the interaction of the Eurasian and African plates, that represents one of the more interesting geodynamical problems in the Mediterranean area. Therefore the monitoring of the local seismicity and its relation to the tectonic features is an important task for the scientific investigation devoted to the seismic risk assessment.

In this frame, most of the daily effort of the research group is dedicated to the management of the Calabrian Regional Seismic Network. This network has the dual role of providing an almost real time monitoring of the area and of incrementing the available waveform data bank. The first is useful in civil protection tasks, the collected information being sent to National Institute of Geophysics and Volcanology, Rome (INGV); the second is the basic instrument to conduct seismotectonic investigations.

In 2009 continued the efforts in the reorganization of the permanent Calabria Seismic Network, taking advantage from the high quality instruments made available in the framework of the ReSiSCal project described in a following section (see sect. 9.5 below), the support from INGV and the long term loan of several instruments from IRIS.

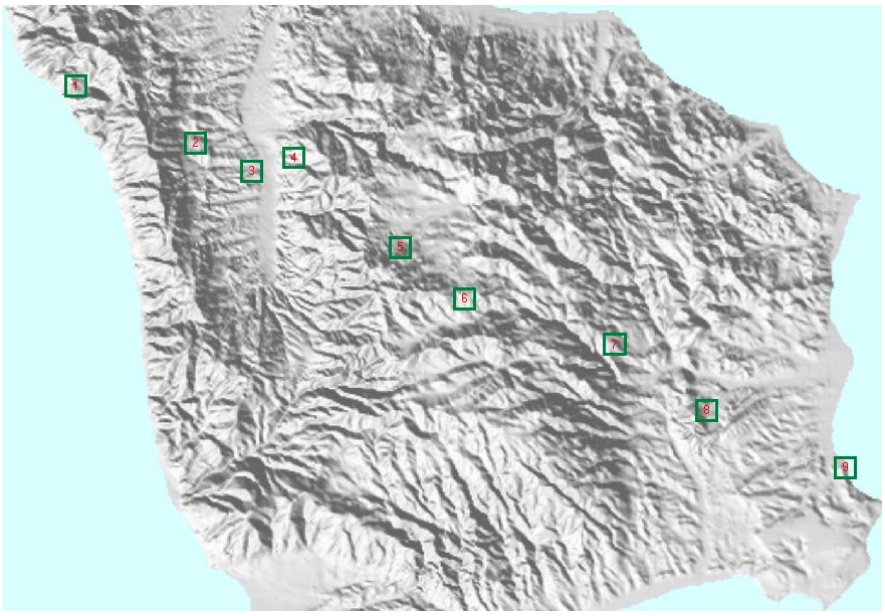
After the first remote station installed in 2007 in the frame of this project was activated, the regular operation of a second one started in 2009. The signals are in both cases forwarded in real time to the recording centre of INGV in Rome too. Test of the possible suitability for seismic stations started in three further sites.

During 2009, the operation continued of the stations residual from the temporary network installed since 2003 in the frame of the CAT/SCAN project in cooperation with the Lamont-Doherty Earth Observatory (Columbia University, New York),.

9.2 Geodesy

Ground deformations is the geophysical phenomenon more frequently associated to the seismic activity in its various stages. It is detected by successive or continuous measurements of the coordinates of reference points (benchmarks). Both classical, optical and modem, GPS techniques can be applied.

In 2009 the Geophysical Group continued in caring the operation of the nine GPS sites installed in 2006 along the transect Cetraro-Crotone (fig. 1) in the framework of CALARCO, a research project in cooperation with the Lamont-Doherty Earth Observatory of the Columbia University. Horizontal displacements observed till 2009 remained smaller than the observation errors, even if they show a coherent pattern.



9.3 Dissemination and diffusion of scientific culture

Noteworthy efforts are dedicated to the diffusion of the geophysical culture, in the attempt of convincing the general public and future university students which too much frequently attribute the seismology to scientific field different from physics.

The Geophysics Laboratory is open to school visits and a set of demonstration tools is available to make seismology understandable and appealing. Every year it is visited by hundreds of pre-university scholars.

A program (ReSiSCal, Rete Sismica Scolastica Calabrese = Scholastic Calabrian Seismic Network) is underway. It will lead to the installation of a seismic network in about ten schools in the whole Calabria. From the instrumental point of view, the collected data are qualitatively equivalent to those from stations activated with purely scientific purposes.

A PUBLICATIONS ON SCIENTIFIC JOURNALS

A.1 Publications on international journals

1. Zimbardo G., Greco A., Veltri P., Voros Z., Amata E., Taktakishvili A.L., Carbone V., Sorriso-Valvo L., Guerra I.:
Solar-Terrestrial relations: magnetic turbulence in the Earth's magnetosphere and geomagnetic activity
Earth Moon Planets, 2009, Vol. 104, n. 1, pp. 127-129.

D PRESENTATIONS AT CONFERENCES

D.1 Presentations at international conferences in 2009

1. D'Agostino N., Gervasi A., Guerra I., Nedimovic M., Seeber L., Steckler M. S.:
Crustal motion of the Calabrian Arc from the CALARCO GPS deployment
AGU Fall Meeting 2009, S. Francisco, USA, Dec 14-18, 2009.

2. Orecchio B.,D'Amico S., Gervasi A., Guerra I., Presti D., Lhu L., Herrmann R., Neri G.:
Moment tensor solutions of recent earthquakes in the Calabrian region (South Italy)
AGU Fall Meeting, S. Francisco, Dec 14-18, 2009.

3. Totaro C., Orecchio B., Presti D., Guerra I., Neri G.:
Seismic velocity structure of the Calabrian Arc subduction system (south italy) and relationships between deep and shallow dynamics
AGU Fall Meeting, S. Francisco, Dec 14-18, 2009.

D.2 Presentations at national conferences in 2009

1. D'Amico S., Orecchio B., Presti D., Gervasi A., Guerra I., Neri G., Zhu L., Herrmann R. B.:
Moment tensor solutions of low magnitude recent earthquakes in the Calabrian-Peloritan Arc region
28° Conv. Ann. Gr. Naz. Geofis. Terra Solida, Trieste, 16-19 novembre, 2009, pp. 102-102.

2. Guerra I., Orecchio B., Sorriso-Valvo M., Gervasi A.:
Primi risultati a carattere locale dalla rete GPS CALABARCO
28° Conv. Ann. Gr. Naz. Geofis. Terra Solida, Trieste, 16-19 novembre, 2009, Trieste, 2009, pp. 575-577.

4. Orecchio B., Presti D., Totaro C., Guerra I.:
Tomographic imaging of P- and S-wave velocity structure beneath the Calabrian Arc region (South Italy): an improved view of the subduction system
28° Conv. Ann. Gr. Naz. Geofis. Terra Solida, Trieste, 16-19 novembre, 2009, pp. 180-181.