

COMPLEXITY RESEARCH IN SPAIN

The Spanish National Research Plan 2004-2007 is structured in several National Programs. A list of specific subjects within the realm of complexity research can be identified in the different Programs. In addition, the National Plan includes a Strategic Action on Complex Systems with emphasis on aspects on dynamics of organizations, logistics and population biology. This Strategic Action is to be developed in 2005. The Spanish MEC is open to launch a call of proposals, and to do it jointly with other one or two countries from the EU.

In the following the highlights of on-going complexity research in Spain are summarized, including areas where higher future impact or windows of opportunity are expected.

PHYSICS

Fundamental problems in complex phenomena are traditionally addressed with concepts and techniques of Statistical and Nonlinear Physics (SNP). The SNP community in Spain is one of the leading research communities in terms of quality and international impact. It is widespread in different universities and research institutes. It organizes itself within the SNP group of the Royal Spanish Physical Society (RSEF). Its regular scientific meetings (13 since 1987) are attended by around 150 scientists. Another near ten years old initiative linking several SNP groups is represented by the network "Nonlinear Dynamics of Spatiotemporal self-organization", funded by the Generalitat de Catalunya and involving eight research groups of six Spanish universities.

Among the many SNP-research groups those that emphasize focused quality research on complexity include IMEDEA (Mediterranean Institute for Advanced Studies, Palma de Mallorca), BIFI (Institute for Biocomputation and Physics of Complex Systems, Zaragoza), GISC (Interdisciplinary Group of Complex Systems, UC3M-UCM, Madrid) and the SNP groups in the Universities of Barcelona and the University of Tarragona. Research topics include Critical phenomena and Phase Transitions, Growth phenomena, spin-glasses, dynamical systems and chaos, coherent nonlinear structures, Computational modelling, biologically motivated problems, etc.

A main area of present and future research is the Dynamics of Complex Networks where Spanish scientists have made a number of recent important contributions. Beyond the intrinsic study of network formation, dynamics on networks and data analysis, research has crossed the traditional boundaries of physics going well within the scope of social sciences, biology, engineering and medical sciences. In addition of the groups mentioned above, significant activity in this area occurs at IFCA (Santander), individuals in different institutes of CSIC-Madrid and University of Alicante. A representative conference on these activities is the Conference on Complex Networks: Evolution and Statistical Properties (Tarragona, March 2005)

SNP Spanish groups have also a long tradition in the study of stochastic phenomena in complex nonlinear systems. Their activity in this field is presently coordinated by their

participation in the “STOCHDYN (Stochastic Dynamics)” program of the European Science Foundation. F. Sagués (Barcelona) is the Spanish member of the steering committee.

MATHEMATICS

There is also an important activity within Mathematics in areas and topics that provide basic methodological tools to the research in Complexity, involving several research groups. In particular, the Spanish network DANCE (Dynamics, Attractors and Nonlinearity: Chaos and Stability), coordinated by Lluís Alsedà (Autonomous University, Barcelona), coordinates research in dynamical systems of most active groups in Spain.

PHYSICS-MATHEMATICS-NATURAL SCIENCES (BIOLOGY, ECOLOGY, GEOLOGY)

A large number of initiatives exist in this interface that emphasize and use general concepts of complexity research. Among those are the following:

IMEDEA (Palma de Mallorca): Joint research between physicists and biologists addresses topics like models of clonal plant growth, networks of genetic structure in marine plants or interactions between biotic components of marine ecosystems in complex flows. A relevant example of this interdisciplinary research is the European IP “THRESHOLDS” coordinated from IMEDEA in which the characterization, origin and consequences of thresholds for regime shift (bifurcations) in ocean coastal ecosystems is considered from different backgrounds (including economy). Physicists at IMEDEA are also engaged in Monte Carlo biosimulation techniques for drug development.

CAB (Center for Astrobiology, Madrid) is a new large research infrastructure offering opportunities to researchers from different disciplines and representing a very important investment effort. It includes laboratories of molecular evolution, molecular ecology, bioinformatics, advanced computation, etc.

BIFI (Institute for Biocomputation and Physics of Complex Systems, Zaragoza): Includes associate members from other Spanish research centres. Collaborative work of physicists, chemists and biochemists and the Molecular Biology and Biochemistry laboratories addresses several problems of biophysics, including protein folding and stability and protein-protein and protein-ligand interactions. Problems of Solid Earth Geophysics and Earthquake occurrence are also addressed.

COMPLEX SYSTEMS LAB (University Pompeu Fabra, Barcelona). In this new lab a group physicist, biologists and engineers considers a variety of biologically inspired problems from the perspective of complexity and with emphasis on complex networks. Research topics include gene networks, theoretical ecology, proteome networks, protein folding and functional genomics, evolution of RNA viruses, and general aspects of Biocomplexity.

Doñana Biological Station (CSIC) is a well known institution for research on evolutionary ecology and population biology with very significant recent work on the

architecture of biodiversity and complex networks of ecological interactions. The Institute participates in the new NEST project UniNet (Unifying networks for Science and Society).

LEC (Laboratory for Crystallographic Studies, CSIC, Granada) is dedicated to a variety of crystallographic problems ranging from macromolecular crystallography to pattern formation and including biomineralization and primitive life detection. The laboratory has an active participation in microgravity mission in space.

From the mathematics side, Castilla-La Mancha University hosts two groups on Biological and Geophysical Fluid Numerical Modelling and Nonlinear waves. They organize the biannual meeting “Nonlinear” bringing together an important number of scientists from Applied Mathematics and Physics in areas related with Complexity. The group on Computational Biology and Bioinformatics in Palma de Mallorca is also worth mentioning. The University of Granada hosts a group on Kinetic Theory, Quantum-Kinetics and Fluid Mechanics. Similar lines of research are being developed in the Autonomous University of Barcelona who recently hosted the HYKE Conference on Complex Flows. The group at the University of Málaga on the Modelling and Numerical simulation of Geophysical Flows is worth mentioning. Research in Fluid Mechanics, Complex flows and its control with applications to aeronautics and Biology is also being developed at the University of the Basque Country, Autonomous and Complutense University of Madrid.

PHYSICS-MATHEMATICS-ENGINEERING

There is important activity in the transfer of fundamental studies of chaos and nonlinear dynamical systems from physics to engineering applications in information science technologies. Examples include the EU project OCCULT on the use of chaotic lasers for secure optical communication coordinated from IMEDEA (Palma de Mallorca), different aspects of optical solitons studied at ICFO (Institute for Photonic Science, Barcelona) or studies of digital chaos generators for secure communications (Polytechnical University of Madrid).

Likewise in Mathematics, the areas of Algebra and Combinatorics include groups with strong involvement in applications to Cryptography. That is the case, for instance, in the University of Oviedo. The University Pompeu Fabra, Barcelona, also hosts a group on Image Processing.

PHYSICS-MATHEMATICS-SOCIAL SCIENCES

A considerable successful effort exists in the interface between physics and the social sciences. Many aspects of this research go under the new headings of Econophysics and Sociophysics. It includes dynamical systems and statistical physics analysis of economic time series data, agent based models of social dynamics, evolutionary game theory and applications of complex network theories. A main common framework of this activity for the Spanish community is the participation in the COST Action P10 “Physics of Risk” of the European Science Foundation. Spanish official representatives in the Cost Action are A. Sanchez (UC3M, Madrid) and M. San Miguel (IMEDEA,

Palma de Mallorca). The community of physicists has also submitted a proposal to the Ministry of Education and Science for a thematic network in this subject coordinated by A. Díaz-Guilera (Barcelona) and R. Toral (IMEDEA, Palma de Mallorca). Several interesting collaborations between physicists and social scientists have been established, in particular with the economist F. Vega (Universities of Alicante and Exeter).

Representative conferences of these activities are the general COST P10 meeting in Toledo (April 2005) and the 8th Granada Seminar on Computational and Statistical Physics: Modelling Cooperative Behavior in the Social Sciences (February 2005) organized by the Institute "Carlos I" for Theoretical and Computational Physics, University of Granada.

The area of Mathematical Finance is also attracting increasing attention from mathematicians which develop activities involving stochastic modelling and analysis. The University of Barcelona hosts an active group in this area, as well as GISC-UC3 (Madrid)

ENGINEERING-COMPUTER SCIENCES-SOCIAL SCIENCES

This is a similar type of research than the one on the interface physics-social sciences but from a different scientific background. One of the active groups in this area is INSISOC (University of Valladolid) that recently organized the 2nd conference of the European Social Simulation Association.

Important R+D activity in this area from the non-academic environment comes from IKERLAN (Mondragón), especially on innovative organization schemes, in collaboration with the London School of Economics.

NEUROSCIENCES

Neuroscience is regarded as a field of clear future impact with expected contributions from physics, engineering, computer sciences, biology, psychology and medicine. There is no presently coordinated action from the point of view of complexity but there are dispersed significant contributions. These include, from a physics perspective, Computational Neurosciences (Autonomous University, Madrid), Modeling neurofunctions and neuroinspired robots (Pluridisciplinar Institute, UC Madrid) and Complex Network Analysis of fMRI data (IMEDEA, Mallorca). Other activities include studies of electrophysiological methods and neurons (Alicante-La Laguna), Chronobiology (Physiology, Univ. of Barcelona) or Magnetoencephalography studies of aesthetic perception (Medicine, UC Madrid-University of Baleares).

POSTGRADUATE TRAINING

The Spanish section of the European Graduate School on Complex systems is also worth mentioning. It is a doctoral program involving several Universities in Madrid, in collaboration with the University of Bayreuth (Germany) and coordinated by A. Sánchez (UC3, Madrid)). A similar program is being developed at the University of Basque Country, coordinated by J. Dolado. The Physics doctoral program of the

University of Zaragoza, includes a subprogram on "Physics of Complex Systems" coordinated by L.M.Flora.