

Publishable Summary

“Dynamics and Cooperative Phenomena in Complex Physical and Biological Media”
PIRES-GA-2010-269139

The collaborative project “Dynamics and Cooperative Phenomena in Complex Physical and Biological Media” (with an acronym “DCP-PhysBio”) PIRSES-GA-2010-269139, established within the SEVENTH FRAMEWORK PROGRAMME Marie Curie Actions People International Research Staff Exchange Scheme (IRSES), aimed, via theoretical modeling and computer simulations, at a basic general understanding and solution of several important problems related to dynamics and cooperative behaviour in complex physical and biological systems. In order to accomplish our program, we built a team of researchers specializing in different aspects of condensed matter physics, statistical physics, polymer science, mathematics, chemical physics and computer science. The project was carried out by several groups from France, Germany, UK, Israel, Russia and Ukraine, with a broad range of expertise: phase transitions and cooperative behaviour, dynamical systems, chemical kinetics, to name just a few. The project linked together groups with either previously well-developed connections, weak or itinerant connections, in order to form a well coordinated multidisciplinary network through an active exchange of researchers stimulating a close collaboration and dissemination of knowledge between partners.

The DCP-PhysBio exchange scheme significantly advanced our understanding and knowledge of cooperative behaviour and dynamics in complex systems resulting in more than 80 scientific publications; involved important scientific partners from such non-EU countries as Russia, Ukraine and Israel; lead to a long-term and large-scale cooperation between the partners in an international "complex media" hub; disseminated the results via organization of four international workshops and three international conferences. The duration of the exchange programme was 4 years, starting from April 2011.

The exchange programme consisted of three work packages, which covered the full duration of the programme. The lead organization for all work packages was Centre National de la Recherche Scientifique (CNRS). Our research was outlined along two principal directions:

- I Phase Transition and Criticality in Complex Systems
- II Dynamics and Reactions in Complex Physical and Biological Systems

Complex systems are generally understood either as systems comprising many interacting entities of non-physical origin (giving rise, in particular, to the so-called exotic problems of statistical physics) or as systems whose behaviour crucially depends on the details of the system. Since all complex systems involve cooperative behaviour between many interconnected components, the field of phase transitions and critical phenomena gives a very natural conceptual and methodological framework for their study. Often complex systems have a network structure by nature. In other cases networks describe mutual interactions of elements of the complex system and can be viewed as its backbone, along which various signals and perturbations may propagate. The statistical, topological and geometrical properties of the network play a crucial role in the description and understanding of collective large range properties of the system. The topology of many natural and man-made networks strongly differs from the topology of the most studied large random or regular graphs. Our objective here was to deal with both aspects of complexity just mentioned, analyzing the systems of non-physical origin as well as studying criticality of traditional physical complex

objects such as disordered magnets or complex polymers.

More specifically, research objectives in work package I were divided (however, non-exclusively) into four groups, involving the analysis of a) peculiarities of the critical phenomena on scale-free networks, b) the influence of structural disorder, frustrations, finite-size effects on the ordering in two- and three dimensional lattice systems and conformational properties of complex polymers, c) the relation between structural properties of networks and their functionality where the network is understood as a skeleton of the complex system on which the interactions between elements of the system propagate and lastly, d) description of criticality in presence of topological disorder, structural anisotropy or frustrations in Ising/Potts model and O(n)-spin models.

The work package II comprised several research tasks, devoted, in particular, to understanding of the first passage phenomena in biological systems, as was exemplified by the so-called Narrow-Escape problem describing molecular trafficking in cellular microdomains, a question of the influence of the inert parts of a substrate on the effective reaction rates for such processes as protein binding to specific sites on DNA molecules or ligand binding to receptor sites on a cell assisted by migration on the cell's surface and diffusion on glycoproteins which serve as antennae, random search in random media, conformational properties of polymers in restricted geometries, single molecule trajectories analysis and a related question of universal generation of fractal statistics, exploration of statistical heterogeneities and problems of barrier crossing in anomalous dynamics.

Our work package III was devoted to the transfer the knowledge, dissemination of results, fostering of already existing and establishing new collaborations within the European Union and also world-wide. Within this work package we organized four international workshops :

- « Search and Exploration I and II », (April 25-29, and June 3-7, 2013, respectively), both held at the premises of the Institut d'Etudes Scientifiques, Cargèse, France
- « Phase Transitions and Critical Phenomena : Ising Lectures », May 28-30, 2013, Lviv, Ukraine
- « Physics Meets Humanities », May 31, 2013, National University of Lviv, Ukraine

The workshops were attended by the members of the Consortium, as well as by many PhD and undergraduate student from the participating teams and local universities.

To disseminate the results, the Consortium participated in organization, either directly or serving as the members of the international advisory boards, of three international conferences, with a wide attendance from the EU countries, as well as from US, Mexico and Canada. These conferences were

- International conference « Fluctuations in Small Complex Systems », October 21-25, 2012, Venice, Italy
- The 4th Conference on « Statistical Physics : Modern Trends and Applications », July 3-6, 2012, Lviv, Ukraine
- « Search and Stochastic Phenomena in Complex Physical and Biological Systems », May 28-June 1, 2012, Palma de Mallorca, Spain

Composition of the participating teams, achievements and publications, as well as the web-sites and programmes of the organized workshops and conferences are summarized at the web-page of the EU IRSES project DCP Phys-Bio : <http://ireses.lptmc.jussieu.fr/index.html>