Real Sociedad Matemática Española

Programa de Doctorado en Física y Matemáticas

Universidad Internacional Menéndez Pelayo

RSME–FisyMat–UIMP Joint Activity in the framework of the 2013 Mathematics of Planet Earth Initiative

Escuela "Luis Santaló": MATHEMATICS OF PLANET EARTH: SCIENTIFIC CHALLENGES IN A SUSTAINABLE PLANET

Santander, July 15 -19, 2013

Directors: Miguel. A. Herrero (U. Complutense), Juan Soler (U. de Granada)

Secretary: Juanjo Nieto (U. de Granada)

Lecturers:
Jordi Bascompte (Integrative Ecology Group, Estación Biológica de Doñana, CSIC, Spain), **Nicola Bellomo** (Politecnico di Torino, Italy), **Joel Brown** (UIC Biological Sciences, University of Illinois at Chicago, USA), **Juan Manuel García Ruiz** (CSIC and University of Granada, Spain), **Robert Gatenby** (Moffitt Cancer Centre, Tampa, Florida, USA), **Jorge M. Pacheco** (University of Minho, Portugal), **Eitan Tadmor** (Center for Scientific Computation and Mathematical Modelling, University of Maryland, USA)

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Programme:

1. THE MATHEMATICS OF BIODIVERSITY (Jordi Bascompte, Integrative Ecology Group, Estación Biológica de Doñana, CSIC, Spain).

The mutualistic interactions between plants and the animals that pollinate them or disperse their seeds can form complex networks involving hundreds of species. These coevolutionary networks show general architectural patterns that increase network robustness to random extinctions and maximize the number of coexisting species. Therefore, they constitute the architecture of biodiversity.

2. TOWARS A THEORY OF COMPLEX LIVING BEINGS (Nicola Bellomo, Politecnico di Torino, Italy).

These Lectures are devoted to the development of mathematical tools for the modelling, qualitative analysis and simulations of complex systems in life and human sciences. The presentation is developed in three steps: i) Detailed analysis of the complexity features of living systems; ii) Analysis of three specific case studies, namely social conflicts, crowd dynamics, and immune competition; iii) derivation of a unified mathematical approach based on methods of the kinetic theory with games described by theoretical tools of game theory. The presentation aims at providing an effective answer to the following questions: Do complex living systems exhibit common features, and which are the analytic and computational tools able to capture these common features?

3. EVOLUTIONARY GAME THEORY: FROM LIFE ON EARTH TO PEST MANAGEMENT AND CANCER (Joel Brown, UIC Biological Sciences, University of Illinois at Chicago, USA).

Topics to be addressed include evolutionary game theory, adaptive & evolutionary dynamics. These will be used to link together modelling, mathematics and conceptual issues ranging from climate change, rapid evolutionary responses in humans, pest management and cancer.

4. PATTERNS ON THE ROCKS (Juan Manuel García Ruiz, CSIC and University of Granada, Spain).

Pattern on the rocks is a pack of three lectures offering a review of the state of the art in mineral pattern formation in the geological record. From simple patterns in giant single crystals to complex shapes mimicking the geometry of life, the lectures provide a pathway across fascinating self-assembled and self-organized mineral formations and the current knowledge about their genetic mechanisms. Issues to be considered include formation of biomorphs, stromatolite structures, chemical gardens and shell and structures, to name but a few.

5. LIVING WITH YOUR ENEMY (Robert Gatenby, Moffit Cancer Centre, Tampa, Florida, USA).

Faced with challenges that seriously threaten human activities and personal survival, mankind has often attempted to fully get rid of the problem raised. However, experience has shown that this strategy is not working in many cases and that coexistence of competing species may be a better goal to pursue. In these lectures evolutionary principles will be used to ensure stability in a few typical situations, namely: long-term management of pests, control of infectious diseases and treatment of chronic disorders such as cancer.

6. EVOLUTION OF DIVERSITY AND COOPERATION (Jorge M. Pacheco, University of Minho, Portugal).

The problem of cooperation. I discuss the problem of the evolution of cooperation under natural selection. I introduce the problem in the framework of evolutionary game theory, showing how so called social dilemmas of cooperation arise and can be understood in this framework, and how cooperation viewed in this way poses a paradoxical disconnect between theoretical expectations and common experience from the real world. Subsequently, I focus on some of the most paradigmatic mechanisms that explain how cooperation has played and keeps playing such an ubiquitous role in the living world at all scales.

Cooperation and Diversity. I will concentrate on the network mechanism leading to the emergence of cooperation, to show how diversity emerges naturally in a world in which individuals interact, influence and are influenced by others through the links of a complex network.

Cooperation, Diversity and Climate Change. In this last lecture I will address the problem of mitigating the adverse effects of accelerated climate change, and how solving this problem can viewed as a N-person cooperation dilemma, decidedly the game that humans cannot afford to loose. I will show how, again, diversity and decentralized governance set the most favourable scenario for overall cooperation to emerge and be sustained.

7. CONSENSUS AND FLOCKING IN SELF-ALIGNMENT DYNAMICS (Eitan Tadmor, Center for Scientific Computation and Mathematical Modelling, University of Maryland, USA)

The topics to be addressed in these lectures include i) Self-organized dynamics by means of agent-based models with focus on a prototype model driven by non-symmetric self – alignment. The dynamics of such systems is governed solely by the interactions among individuals, with the tendency to adjust to their environmental averages, ii) Unconditional consensus and flocking, where the self-organized behaviour tends to concentrate in one cluster, thus reflecting a consensus of opinions, flocking or concentration of other positions intrinsic to the dynamics, and iii) Heterophilious interactions. The idea to be pursued here is that heterophily, the tendency to bond more with those who are different rather than with those who are similar, plays a decisive role in the process of clustering. This is in sharp contrast with the widely accepted assumption of a tendency to align with those who think or act alike.