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RESEARCH CONFERENCES

ESF-EMS and Mathematics Conference

Applied PDEs in Physics, Biology and Social Sciences: Classical and Modern Perspectives

Centre de Recerca Matemàtica, Bellaterra • Spain
2 – 7 September 2012

Chaired by:

Dr. Marco Di Francesco, Universitat Autònoma de
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Professor José Antonio Carrillo de la Plata, ICREA &
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Highlights & Scientific Report



© Applied Partial Differential Equations: A Visual Approach by Markowich, Peter

Conference Highlights

Please provide a brief summary of the conference and its highlights in non-specialist terms (especially for highly technical subjects) for communication and publicity purposes. (ca. 400-500 words)

"Differential calculus, as introduced by Sir Isaac Newton and Gottfried Wilhelm Leibniz in the late 17th century, opened up a wealth of new possibilities for mathematical modeling in the natural and – later on – in the life sciences and in technology. Partial Differential Equations (PDEs), entirely based on the concept of differential and integral calculus, relate one or more state variables to their variations (differentials) with respect to certain independent variables like time, space, velocity etc. Just to name a few examples, PDEs were used by James Clerk Maxwell to model electromagnetic fields interacting with charges and currents, by Ludwig Boltzmann to describe the non-equilibrium dynamics of rarefied gases, by Albert Einstein to phrase the laws of gravitation in the general theory of relativity and by Erwin Schroedinger and Werner Heisenberg to formulate quantum mechanics in mathematical-analytical terms." (Peter A. Markowich, Applied Partial Differential Equations, A visual approach, Springer, 2007).

In the last decades - in addition to their strong historical link with physics and engineering - partial differential equations provided a new mathematical interpretation of models arising from biology and social sciences. Keywords such as stability and instability, pattern formation, blow up, as well as singular limits and mean-field limits, turned out to be mathematical-analytical counterparts to several phenomena occurring in nature such as cells aggregation in microbiology, collective behavior (flocking, herding etc.) in animal biology, consensus of opinions in a human community in social sciences

The main focus of the conference was to provide an overview of the recently developed mathematical theories within mathematical analysis and mathematical physics, which provided a valid interpretation to the afore mentioned applied phenomena, with a few significant examples arising from numerical analysis. To mention few important theories in this sense, we mention the use of optimal transport and gradient flows, which provided a sound basis to study mean-field PDEs arising in electromagnetism and quantum semiconductor theory, as well as in cell biology (chemotaxis) and population dynamics. More examples are the use of kinetic Boltzmann-type equations in socio-economical sciences, the hydrodynamical Euler-type formulation of several problems in medicine (cancer formation, emodynamics), the modeling of pedestrian flows via nonlinear conservation laws.

The conference hosted world leaders in the area of Analysis of PDEs such as Andrea Bertozzi (UCLA), Tai Ping Liu (Ac. Sinica Taipei and Stanford), Robert McCann (Toronto), Eithan Tadmor (Maryland), Angela Stevens (Muenster), Juan J. L. Velazquez (Bonn), Panagiotis Souganidis (Chicago), Benoit Perthame (Univ. P. & M. Curie, Paris), Laurent Desvillettes (ENS Cachan) and Juan Luis Vazquez (Madrid). The massive presence of overseas expert gave the conference the label of primary international event within the scientific area. The presence of Alfio Quarteroni (EPFL) meant to enrich the conference with a world leading expertise from the world of numerical analysis and real life applications. Although the programme was pretty dense, short talks from young post doctoral researchers, as well as poster sessions for PhD students was provided.

I hereby authorize ESF – and the conference partners to use the information contained in the above section on

'Conference Highlights' in their communication on the scheme.

Scientific Report

Executive Summary

(2 pages max)

This conference addressed emerging topics in the analysis of partial differential equations with applications to biology, physics, and social sciences, with a strong focus on modern applications. In particular, a main focus was devoted to the following topics:

- 1) PDE models in neurosciences
- 2) Blow-up phenomena in physics and biology
- 3) Swarming and aggregation models
- 4) Kinetic models and their continuum limits
- 5) Transport equations in fluid dynamics
- 6) Dispersive equations arising in quantum mechanics
- 7) Theory of systems of conservation laws
- 8) PDE models related with probability
- 9) Nonlinear diffusion equations
- 10) Transport equations in material sciences
- 11) Diffusion models in population dynamics
- 12) Modeling of flocking and social consensus
- 13) Mathematical modeling in biomedical sciences

World leaders in these areas who participated to the conference are Andrea Bertozzi (UCLA), Panagiotis Souganidis (Chicago), Tai-Ping Liu (Ac. Sinica and Stanford), Juan Luis Vazquez (Madrid), Eitan Tadmor (Maryland), Benoit Perthame (Paris 6), Jean Dolbeault (Paris Dauphine), Robert McCann (Toronto), Giuseppe Toscani (Pavia); Juan J. L. Velazquez (Bonn), Angela Steves (Muenster).

40% of the time was devoted to short talks from senior applicants, including Johannes Zimmer (Bath), Christian Schmeiser (Vienna), Piotr Biler (Wroclaw), and Razvan Fetecau (Simon Fraser).

A poster session (with a wine and cheese reception) gave the possibility to 20 selected junior researchers and PhD students to present their work. The session was a great success in participation.

The conference was organized at the CRM Bellaterra, a very modern and equipped structure in the Autònoma University Campus near Barcelona. The participants could enjoy all the facilities at the campus, in a very constructive and inspiring atmosphere for research and collaboration, as all the participants highlighted in their feedback. A social event was organized on Wednesday afternoon, with a guided tour of the city of Barcelona and with a social dinner in the city center.

The scientific outcome of the conference is clearly that of an event with a deep impact on the PDE community, in terms of newly established collaborations, of a new “bridge” of work opportunities between Europe and USA/Canada (on both directions), and of the focus of newly emerging topics, as highlighted in the Forward Look section.

The conference was a great spot for the quality of the European research within the world scientific community.

Scientific Content of the Conference

(1 page min.)

The first session on Monday morning was devoted to PDE models in neurosciences. Benoit Perthame (Univ. Pierre et Marie Curie) overviewed results on this area in the context of equations of structured population dynamics, Maria del Mar Gonzales (UPC Barcelona) presented a recent result on a diffusive model with singular source, which incorporates a free boundary problem.

In the second morning session on Monday, blow-up phenomena with various applications have been described. Juan José Velazquez (Bonn) presented a recent result on a Boltzmann equation with cubic nonlinearity arising in Bose-Einstein particle theory, Piotr Biler presented a blowup and self-similar solutions result for two component drift-diffusion system.

The whole afternoon session on Monday was entirely devoted to swarming and aggregation models with various application. This area in the last years has seen in Andrea Bertozzi (UCLA) one of its major and more productive contributors. In her talk she gave an overview of those results, by focusing mostly on the case without diffusion. The next talk by Fazvan Fetecau (Simon Fraser Univ Vancouver) was devoted to a special case with singular aggregation and repulsion, in which he proves existence and uniqueness of radial steady states. A major contribution in this context is that of Angela Stevens (Muenster), who is widely considered as a major expert in this area especially due to her application-oriented viewpoint, which takes profit of her longstanding interaction with biologists. The session was concluded with the two talks by Jesus Rosado (UCLA) and Sabine Hittmeir, both on aggregation equations of Keller-Segel type.

The first session on Tuesday morning was oriented towards kinetic models and their continuum limits. Robert McCann (Toronto) is a top expert on fast diffusion type equations; his talk was devoted to a recent result he achieved on improved decay estimates towards Barenblatt profiles by fixing higher order moments. Giuseppe Toscani (Pavia) reviewed a theory he developed in the last 5 years with the help of many colleagues (including economists) which uses kinetic equations to model goods exchange in microeconomics. Karsten Matthies (Bath) reported on a justification of the Boltzmann equation in terms of collision trees.

A special session within the whole program was the second one on Tuesday, which has been thought as a session with a special push towards applications. We have been particularly proud of having Alfio Quarteroni (EPFL) as plenary speaker: he gave a wide overview of the computational and numerical results he achieved throughout his recent career, with special focus on models for the cardiovascular system. Alethea Barbaro (Case Western) has a longstanding collaborations with marine biologists, she reported on various results in models for the movement of fishes and on more recent models for social animal behavior.

The first afternoon session was devoted to transport equations in fluid dynamics. Camillo De Lellis (Zurich) is currently working on a long standing mathematical conjecture on the regularity of solutions of incompressible Euler. Gianluca Crippa (Basel) used geometric measure theory to tackle the uniqueness of a two dimensional transport equation. The last afternoon session was devoted to dispersive equations arising in quantum mechanics. Francois Golse (Ecole Polytechnique) presented results related with the Wigner measure approach to the Schroedinger equation. The talk by Weizhu Bao (Singapore) was devoted to present several numerical approaches to the nonlinear Klein-Gordon equation in the nonrelativistic limit regime.

The first half of the morning session on Wednesday has been focused on systems of conservation laws. We had the pleasure of hosting a worldwide leading expert such as Tai-Ping Liu (Stanford and Ac. Sinica), who devoted his talk to the boundary relations for dissipative hyperbolic systems. Pierangelo Marcati (L'Aquila) presented in deep detail a recent result on a quasi neutral limit arising in plasma physics. Evgeniy Panov (Novgorod) devoted his talk to the decay of entropy solutions to scalar conservation laws with weak regularity assumptions on the flux.

The second session on Wednesday contained all the contributions with a non empty intersection with probability theory. Panagiotis Souganidis (Chicago) gave an extensive overview of results on random homogenization for fully nonlinear PDEs. Johannes Zimmer (Bath) reported on a recent results connecting the Wasserstein gradient flow theory with large deviation theory. Finally, the talk by Marie Wolfram (Vienna) was devoted to the mean field game interpretation of the modeling of pedestrian movements.

The first morning session on Thursday was devoted to a by now classical argument in the applied mathematics community, namely nonlinear diffusion. One of the fathers of the theory is Juan Luis Vazquez (Madrid), who has described recent results on the case with fractional Laplacian. A model with saturated diffusion has been proposed by Vicent Caselles (UPF Barcelona). Daniel Matthes (TU Munich) presented a recent result on the connection between entropy solutions and gradient flow solutions for convection diffusion equations.

The second morning session was devoted to models in material sciences. Christian Schmeiser (Vienna) presented a result related with stable length distributions for biopolymers. Anton Arnold (TU Vienna) considered the large time behavior of polymeric fluid flows.

The first afternoon session on Thursday was devoted to various models in population dynamics, with the major contribution being the one by Laurent Desvillettes (Cachan), one of the world leader experts in nonlinear reaction diffusion systems, who reviewed several results in this context. Mats Gyllenberg (Helsinki) presented a result on a model arising from paleontology. Gael Raoul (CNRS) considered populations structured by a phenotypic trait and a space variable.

The last session on Thursday was devoted to cross diffusion and higher order equations. Ansgar Juengel (TU Vienna) reviewed recent advances on the entropy structure of cross-diffusion systems. Carlota Cuesta (Madrid) presented a result on the thin film equation.

With the one exception of the concluding talk, the morning session on Friday was devoted on first and second order nonlocal models arising in social dynamics, with major focus on flocking and consensus phenomena. Eitan Tadmor (Maryland) devoted large part of his latest career to this topic. He presented various approaches on second order models such as Cucker-Smale and related systems for flocking. Jean Dolbeault (Dauphine) devoted his talk on the interplay between the two dimensional Keller-Segel system and the fast diffusion equation. Trigve Karper (Maryland) went back to flocking models and introduced several multiscale issues. Jian Guo Liu (Duke) focused on phase transition of self-alignment in flocking dynamics. The last talk of the conference by Martin Burger (Muester) was entirely devoted to recent achievements in the mathematical modeling in the biomedical sciences, with special focus on transport reaction diffusion models in neurosciences.

Forward Look

(1 page min.)

The conference attracted many leading expert and young researchers from all over the world (Europe, North America, Asia, Africa), and had a great impact in terms of interaction among people from different research backgrounds and interdisciplinarity. We had the honour to host one of the greatest applied mathematicians of our times such as Andrea Bertozzi, Takis Souganidis, and Alfio Quarteroni, as well as longstanding and well established leaders in their areas such as Tai-Ping Liu, Juan Luis Vazquez, Benoit Perthame, Jean Dolbeault, Laurent Desvillettes, and Eitan Tadmor. The large percentage of young researchers and students (there was a poster session with 21 presentations) made the conference a great occasion for interplay and transfer of knowledge and expertise. The discussion sessions after each talk have been very intense and successful, and people have established collaborations after meeting at this conference for the first time (e.g. J. Zimmer and P. Biler).

We are very proud to quote from an email we received from Andrea Bertozzi after the conference: "I made some good contacts here especially with young people and I am going to follow up on that. I think one is going to apply for a postdoc in my group and the other will come and visit hopefully for a month." This is just one example of spin-off related to this conference.

Another important point to stress is the financial sponsorship we received from the French ANR project CB-Dif, which allowed around 10 French participants to take part to the conference.

Quoting a feedback from Prof. Tai-Ping Liu (Stanford) "I am impressed by the quality of European research", this conference provided a spot for research in applied mathematics of paramount importance for the European Research, in times in which the financial crisis is rendering the support to basic research a difficult task. The interdisciplinary target of the conference provided an extremely high rate of cultural exchange between the participants, with spin-off to the set up of new collaborations. Moreover, people working on similar mathematical problems (e.g. Martin Burger, from Muenster, and Razvan Fetecau, from Simon Fraser University) have met at this conference for the first time, and have started a new collaboration on nonlocal interaction equations. More generally, the feedback on the scientific impact of this conference on existing and future research was outstanding.

A major point to be highlighted is the view on applications. The interplay among longstanding experts in classical theories arising from mathematical physics and people interested in newly developed applications to biology and social sciences was of paramount importance in order to stress the need for a more rigorous derivation for models e. g. in biology. The revival of discrete models and mean field limit in socio-biology is another example in which classical tools are now used in those new models.

The revival for discrete modeling among PDE experts is a very clear outcome of this conference, being mostly motivated by the need of providing the mean-field "continuum" counterparts with an "individual based" model providing a closer view on the applications in micro-biology and social sciences. In this sense, the need of a discrete modeling not necessarily linked with stochastic analysis is getting a newly emerging task.

A more and more emerging focus is being put on systems with many species, in the context of both reaction diffusion / cross diffusion and hydrodynamic models. Such aspect is very important in order to provide a mathematical interpretation to segregation phenomena and multiple collapse in biophysical systems.

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

No

Business Meeting Outcomes

- *Election of the Organising Committee of the next conference*
- *Identified Topics*
- *Next Steps*

Atmosphere and Infrastructure

- *The reaction of the participants to the location and the organization, including networking, and any other relevant comments*

The invitees could enjoy the modern and well equipped and modern structure at the CRM Bellaterra, and could spend most of the time in a very inspiring atmosphere for collaboration at the UAB campus, as well as a social event in Barcelona. Feedback from the participants provided evidence of extremely fruitful contacts between people meeting for the first time, as well as seeds for newly established collaboration. In this sense, the interdisciplinary cut of the programme was an added value.

The coffee and lunch breaks, as well as the dinner time, has been very profitable for interaction. Although the program was very intensive, many people have interacted during the free time. The poster session was an absolute success in terms of participation of young and senior researchers.

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Date & Author:

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