# CURRICULUM VITÆ

Francesco Vecil

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# 1 Curriculum vitæ

## 1.1 Personal information

- **Family name:** Vecil.
- **Given name:** Francesco.
- **Birth date and place:** 21 February 1978, Udine (Italy).
- **Citizenship:** Italian.
- **Address:** 48, rue Eugène Gilbert, apt. 11, 63000 Clermont-Ferrand (France).
- **Address 2:** via Como, 37/B, 33100 Udine, Italy.
- **Address 3:** calle Mallorca, 494, $1^o$, $2^a$, Barcelona E08013, Spain.
- **Professional address:** Laboratoire de Mathématiques, Université Blaise Pascal (Clermont-Ferrand 2), UMR 6620 - CNRS - Campus des Ćzeaux - B.P. 80026, 63171 Aubière cedex (FRANCE).
- **Mobile phone contact:** +33 (0)785764194 (France), +34 635924630 (Spain), +39 3291298154 (Italy).
- **E-mail:** francesco.vecil@gmail.com
- **Skype contact:** francesco.vecil

## 1.2 Positions held

- **01 October 2002-30 September 2006**: Ph.D. student at the Universitat Autònoma de Barcelona, supervisor José Antonio Carrillo, with Ph.D. fellowship IGSOC-IQUC from the Catalan government.
- **01 October 2006-30 September 2007**: Ph.D. student at the Université de Toulouse, co-supervisor Naoufel Ben Abdallah, with a European DEASE-Marie Curie fellowship.
- **01 October 2007-30 November 2007**: Ph.D. student at the Universitat Autònoma de Barcelona with a fellowship of the research group on numerical simulation of PDEs.

- **01 April 2008-30 September 2008**: post-doctoral position at the Universidad de Granada in the project “Ingenio Mathematica” (CSD2006-0032) in order to realize “Deterministic quantum model for 2D MOSFETs. Comparison with Monte Carlo and parallel implementation on a cluster of PCs”, funded by the Spanish ministry for Education and Culture.

- **01 October 2008-30 September 2010**: post-doctoral position at the Radon Institute for Computational and Applied Mathematics, Austrian Academy of Sciences, Linz (Austria).

- **01 October 2010-30 August 2013**: post-doctoral position, with a Juan de la Cierva fellowship of the Spanish ministry, at the Applied Mathematics department, Universitat de València (Spain).

- **01 September 2013-**: maître de conférences (assistant professor) at the Université Blaise Pascal, Clermont-Ferrand (France).

## 1.3 Academic certificates

- **12/07/2002:** Degree in Mathematics, Università degli Studi di Padova, Italy.
  **Degree thesis:** Asynchronous exponential growth in age-structured populations.
  **Supervisors:** Rosanna Bressan Villella, Lorenza Tonetto.

- **2005:** Diploma de Estudios Avanzados (Master) in Applied Mathematics, Universitat Autònoma de Barcelona (Spain).
  **Research project:** Non-oscillatory interpolation methods applied to kinetic equations for plasmas.
  **Supervisor:** José Antonio Carrillo.
  **Committee:** Lluís Alsedà, Francesc Xavier Mora, Josep Maria Mondelo.

- **17/12/2007:** Ph.D. degree, Universitat Autònoma de Barcelona (Spain).
  **Thesis title:** A contribution to the simulation of Vlasov-based models.
  http://www.tesisenxarxa.net/TDX-0314108-170950/
  **Supervisors:** José Antonio Carrillo, Naoufel Ben Abdallah.
  **Committee:** Rosa Donat, Josep Maria Mondelo, María J. Cáceres, Stéphane Cordier, Armando Majorana.

- **17/12/2007:** European Ph.D. degree, Universitat Autònoma de Barcelona (Spain).

## 1.4 Teaching résumé

- **Numerical integration of PDEs**, 30 hours, academic year 2005-06, Mathematics department, Universitat Autònoma de Barcelona (Spain).
- **Hyperbolic conservation laws**, 14 hours, academic year 2009-10, Johannes Kepler Universität, Linz (Austria).
- **Mathematics II**, 60 hours, academic year 2011-12, Chemical Engineering, Universitàt de València, Burjassot - València (Spain).
- **Mathematics II**, 60 hours, academic year 2012-13, Chemical Engineering, Universitàt de València, Burjassot - València (Spain).
- **Numerical Analysis**, 68 hours, academic year 2013/14, L1 ISIMA, Clermont-Ferrand (France).
- **Integrals and resolution of differential equations**, 28 hours (TD), academic year 2013/14, L3 Physics, Université Blaise Pascal, Clermont-Ferrand (France).
- **Numerical Analysis**, 14 hours (TD), academic year 2013/14, Polytech, Clermont-Ferrand (France).
- **Series and Differential Calculus**, 56 hours (TD), academic year 2013/14, L2 Physics, Université Blaise Pascal, Clermont-Ferrand (France).
- **General Mathematics 2**, 30 hours (TD), academic year 2013/14, L1 Mathematics, Université Blaise Pascal, Clermont-Ferrand (France).
- **Module Mathématiques A/B**, 85 h., academic year 2014-15, L1, Université Blaise Pascal, Clermont-Ferrand (France).
- **Mathématiques (21MP31)**, 30 h., academic year 2014-15, L2, Université Blaise Pascal, Clermont-Ferrand (France).
- **Intégrales (31MM59)**, 26 h., academic year 2014-15, L3, Université Blaise Pascal, Clermont-Ferrand (France).
- **Harmonisation 2 (41FM12)**, 16 h., academic year 2014-15, M1, Université Blaise Pascal, Clermont-Ferrand (France).
- **Mathématiques Générales 2 (11MM22)**, 30 h., academic year 2014-15, L1, Université Blaise Pascal, Clermont-Ferrand (France).
- **Analyse Numérique (370P6NUM)**, 14 h., academic year 2014-15, Polytech, Clermont-Ferrand (France).

- **Module A ou B Mathématiques (11MM11)**, 85 h., academic year 2015-16, L1, Université Blaise Pascal, Clermont-Ferrand (France).
- **Mathématiques (21MP31)**, 30 h., academic year 2015-16, L2, Université Blaise Pascal, Clermont-Ferrand (France).
- **Intégrales, résolution d'équations différentielles (31MM59)**, 26 h., academic year 2015-16, L3, Université Blaise Pascal, Clermont-Ferrand (France).
- **Harmonisation - Méthodes numériques (41FM12)**, 16 h., academic year 2015-16, M1, Université Blaise Pascal, Clermont-Ferrand (France).
- **Mathématiques appliquées à la chimie (21MM311)**, 25 h., academic year 2015-16, L2, Université Blaise Pascal, Clermont-Ferrand (France).
- **Méthodes numériques (31MM55)**, 14 h., academic year 2015-16, L2, Université Blaise Pascal, Clermont-Ferrand (France).

## 1.5 Research résumé

**Main research fields:**

- WENO, semi-Lagrangian, Strang splitting, finite-differences Runge-Kutta, Adaptive Mesh Refinement and discontinuous-Galerkin methods for hyperbolic and kinetic equations;
- realistic simulation of a nanoscaled MOSFET;
- simulation of laser-plasma interaction models and of the guiding-center model for plasma physics;
- simulation of particle and kinetic models for swarming;
- simulation of radiative transfert models.

**Résumé.** My research activity has developed around the numerical simulation of problems having an interest for physics or engineering, namely the simulation of semiconductors, plasmas, collective behavior models and the radiative transfert equation.

During my Ph.D. studies I validated numerical methods based on WENO interpolation and splitting on kinetic test cases of increasing difficulty, from linear advection, passing through the Vlasov-Poisson model, up to a Boltzmann-Schrödinger-Poisson system to describe the transport and the eigenstates inside nanoscaled MOSFETs, for which quantum effects become non-neglectable. Moreover, I afforded the simulation of problems related to plasma physics, with a 1D model describing the laser-plasma interaction.

During my post-doctoral positions (Granada 2008, Linz 2008-2010 and Valencia 2010-), I have begun several research lines: the CPU and GPU parallelization of the solver for the nanoMOSFETs; the simulation of particle and kinetic collective behavior models; thanks to the participation to the cemracs 2010, a Discontinuous Galerkin scheme for the guiding-center model, involved in fusion energy models; the implementation of a Discontinuous Galerkin method for the radiative transfert equation, interesting for medical purposes; application of an Adaptive Mesh Refinement strategy to semi-Lagrangian solvers for hyperbolic conservation laws and to the Vlasov-Maxwell system for laser-plasma interaction.

## 1.6 Publications

1. J.A. Carrillo, F. Vecil, "Non oscillatory interpolation methods applied to Vlasov-based models", **SIAM Journal on Scientific Computing** 29, 1179-1206, 2007.

2. J.A. Carrillo, A. Majorana, F. Vecil, "A Semi-lagrangian deterministic solver for the semiconductor Boltzmann-Poisson system", **Communications in Computational Physics** 2, 1027-1054, 2007.

3. J.A. Carrillo, T. Goudon, P. Lafitte, F. Vecil, "Numerical Schemes of Diffusion Asymptotics and Moment Closures for Kinetic Equations", **Journal of Scientific Computing**, 35, 113-149 (2008).

4. N.B. Abdallah, M.J. Cáceres, J.A. Carrillo, F. Vecil, "A deterministic solver for a hybrid quantum-classical transport model in nanoMOSFETs", **Journal of Computational Physics**, vol. 228, nr. 17, 6553-6571 (2009).

5. J. A. Carrillo, M. Fornasier, G. Toscani, F. Vecil, "Particle, Kinetic, and Hydrodynamic Models of Swarming", in Naldi, G., Pareschi, L., Toscani, G. (eds.) **Mathematical Modeling of Collective Behavior in Socio-Economic and Life Sciences**, Series: Modelling and Simulation in Science and Technology, Birkhauser, (2010), 297-336.

6. Pep Mulet, Francesco Vecil, "A semi-Lagrangian AMR scheme for 1D and 2D hyperbolic conservation laws", **Journal of Computational Physics** vol. 237 (2013), 151–176.

7. Francesco Vecil, Pauline Lafitte, Jesús Rosado, "Numerical analysis on attraction/repulsion collective behavior model", **Physica D Nonlinear Phenomena**, special issue related to the BIRS meeting, vol. 260 (2013), 127–144.

8. Francesco Vecil, José Miguel Mantas, María J. Cáceres, Carlos Sampedro, Andrés Godoy, Francisco Gámiz, "A parallel deterministic solver for the Schrödinger-Poisson-Boltzmann system in ultra-short DG-MOSFETs: Comparison with Monte Carlo", **Computers and Mathematics with Applications** vol. 67 (2014), 1703–1721.

9. Francesco Vecil, Pep Mulet, Simon Labrunie, "WENO schemes applied to the quasi-relativistic Vlasov-Maxwell model for laser-plasma interaction", accepted for publication in **Comptes Rendus de Mécanique** for the special issue "Theoretical and Numerical Approaches for Vlasov-Maxwell Equations" (2014).

**Proceedgins.**

1. Fischer, M., Moriarty J., Nordhausen, K., Panov, I. and Vecil, F. (2006): "Dynamic Traffic Control". In Heiliö, M. and Kauranne, T. (editors) **Proceedings of the 18th ECMI Modelling Week 13.-21. August 2004**, 39-47, Research Report 101, Lappeenranta University of Technology, Lappeenranta.

2. Nicolas Crouseilles, Michel Mehrenberger, Francesco Vecil, "Discontinuous-Galerkin semi-Lagrangian method for Vlasov-Poisson", **CEMRACS 2010 research achievements: numerical modeling of fusion**, ESAIM: proceedings vol. 32, (2011), 211-230.

**Works in progress.**

1. María J. Cáceres, Francisco Gámiz, Andrés Godoy, José Miguel Mantas, Carlos Sampedro, Francesco Vecil, "The impact of the surface roughness in the Schr̈dinger-Poisson-Boltzmann solver for ultra-short DG-MOSFETs".

2. María J. Cáceres, José Miguel Mantas, Francesco Vecil, "GPU implementation of the Schr̈dinger-Poisson-Boltzmann solver for ultra-short DG-MOSFETs".

3. Antonio Baeza Manzanares, Simon Labrunie, Pep Mulet Mestre, Francesco Vecil, "An electrodynamic AMR solver for the quasi-relativistic Vlasov-Ampère-Maxwell model".

4. Massimo Fornasier, Francesco Vecil, "Numerical analysis on Cucker-Smale collective behavior models".

5. Nicolas Crouseilles, Michel Mehrenberger, Francesco Vecil, "A Discontinuous-Galerkin semi-Lagrangian scheme for the guiding-center problem".

6. Pauline Lafitte, Francesco Vecil, "Two-dimensional continuum simulation of attraction/repulsion collective behavior models".

7. Armando Majorana, Francesco Vecil, “A Discontinuous-Galerkin solver for the radiative transfer equation”.

## 1.7 Seminars and talks

- **Semi-Lagrangian method for pointwise WENO interpolation**. Département de Mathématiques, Université de Nancy (France). 1 June 2005. **Seminar**.

- **Non oscillatory interpolation methods applied to kinetic equations for plasmas**, Journées EDPs et Applications, Communauté de Travail des Pyrénées. Université Paul Sabatier, Toulouse (France). 30 September 2005. **Seminar**.

- **A solver for a coupled quantum-classical model for nanoMOSFETs**, DEASE Summer-school and Annual Meeting. Wolfgang Pauli Institut, Vienne (Austria). 09-14 July 2007. **Talk**.

- **Hybrid model for 2D quantum transport**, International Workshop in Computational Electronics. University of Massachusetts, Amherst MA (États Unis). 08-10 October 2007. **Poster**.

- **A semi-Lagrangian deterministic solver for a hybrid quantum-classical nanoMOSFET**, COMSON International Summer School on Modelling and Optimization for the Design of Electronic Circuits and Devices. Baia Samuele, Sampieri (Italy). 14-21 June 2008. **Talk**.

- **A semi-lagrangian deterministic solver for a hybrid quantum-classical nanoMOSFET**, minisymposium “M15: Mathematical Problems from Semiconductor Industry”. SIMAI $9^{th}$ congress, Roma (Italy). 15-19 September 2008. **Talk**.

- **Splitting methods for the solution of electron transport in semiconductors**, Radon Institute for Computational and Applied Mathematics, Linz (Austria). 7 October 2008. **Seminar**.

- **A deterministic hybrid quantum/classical solver for a nanoscaled MOSFET device**, Quantum Systems and Semiconductor Devices: Analysis, Simulation, Applications. Peking University (Chine). 20-24 April 2009. **Talk**.

- **Simulation of a Double Gate MOSFET through a hybrid quantum/classical model**, PDEs in Engineering Nanoscience and Biology. Hotel Le Royal, Hammamet (Tunisia). May 2010. **Talk**.

- **Simulation of a Double Gate MOSFET through a hybrid quantum-classical model**, minisymposium “Advanced Numerical Simulations for Kinetic Equations”. Joint SIAM/RSME-SCM-SEMA Meeting Emerging Topics in Dynamical Systems and Partial Differential Equations, Barcelona (Spain). 31 May-4 June 2010. **Talk**.

- **Realistic simulation of a Double Gate MOSFET through a hybrid quantum-classical model**, minisymposium “MSP23 - Mathematical Models and Numerical Methods for Charge Transport in Semiconductors”. Joint SIMAI/SEMA conference on Applied and Industrial Mathematics, Cagliari (Italy). 21-25 June 2010. **Talk**.

- **Simulation of a Double Gate MOSFET through a hybrid quantum-classical model**, minisymposium “MSP34 - New Trends in Kinetic Theory”. Joint SIMAI/SEMA conference on Applied and Industrial Mathematics, Cagliari (Italy). 21-25 June 2010. **Talk**.

- **Some applications of kinetic equations**, Departament de Matemàtica Aplicada, Universitat de València (Spain). 23 February 2011. **Seminar**.

- **Simulation of sub-band model for ultra-short DG MOSFET devices**, held at the congress in memory of Naoufel Ben Abdallah “Kinetic models of classical and quantum particle systems”, Institut de Mathématiques de Toulouse (France), 14-18 March 2011. **Talk**.

- **Implementación de simuladores realistas de dispositivos DG-MOSFET a nanoescala en plataformas de altas prestaciones** (Implementation of a realistic solver for nanoscaled DG-MOSFET devices on high-performance platforms), held at the Department of Applied Mathematics, Universidad de Granada (Spain), 12 July 2011. **Seminar**.

- **AP schemes for intermediate models between a kinetic equation and its diffusive limit**, held at the 9th International Conference of Numerical Analysis and Applied Mathematics (ICNAAM 2011), G-Hotels, Halkidiki (Greece), 19-25 September 2011. **Talk**.

- **Numerical analysis of attraction/repulsion collective behavior models**, conference “Analysis, Modeling and Simulation of Collective Dynamics from Bacteria to Crowds” held at the CISM (International Center for Mechanical Sciences), Udine (Italy), 9-13 July 2012. **Talk**.

- **A semi-Lagrangian AMR scheme for 2D transport problems in conservation form**, minisymposium “Adaptive Numerical Techniques for Partial

Differential Equations", conference "WONAPDE 2013, Fourth Chilean Workshop on Numerical Analysis of Partial Differential Equations" held at the Universidad de Concepción, Concepción (Chile), 14-18 January 2013. **Talk**.

- **A semi-Lagrangian AMR scheme for 2D transport problems in conservation form**, session "Numerical Methods for Partial Differential Equations", conference "CSASC 2013", held at Koper/Capodistria (Slovenia), 9-13 June 2013. **Talk**.

- **Deterministic simulation of a DG-MOSFET through a parallel solver**, JERAA 2013, held at Saint-Étienne (France), 22 November 2013. **Talk**.

- **Semi-Lagrangian Adaptive-Mesh-Refinement method for transport problems**, journée de l'équipe EDPAN, Laboratoire de Mathématiques, UBP, 16 January 2014. **Seminar**.

- **Deterministic simulation of a DG-MOSFET through a parallel solver**, held at Laboratoire Jean Kuntzmann, Grenoble (France), 7 February 2014. **Seminar**.

- **Deterministic simulation of a DG-MOSFET through a parallel solver**, held at the 2014 ECMI congress, Taormina (Italy), 13 June 2014. **Talk**.

- **A parallel deterministic solver for a DG-MOSFET device**, held at the Department of Applied Mathematics, Universitat de València, Burjassot (Spain), 24 July 2014. **Seminar**.

- **A parallel deterministic solver for DG-MOSFETs**, held at the Workshop on PDEs: Modelling, Analysis and Numerical Simulations, Granada (Spain), 18 September 2014. **Talk**.

- **Simulación determinista de un MOSFET de doble puerta. Implementación paralela**, Granada (Spain), 19 June 2015. **Seminar**.

## 1.8 Administrative activities and other competences

### 1.8.1 Referee activity

Activity of refereeing for the following journals:

- Communications in Computationl Physics.

- Journal of Computational and Applied Mathematics.

- Journal of Scientific Computing.

- Journal of Computational and Theoretical Transport.

### 1.8.2 Conference and workshop organisation

- **Minisymposium "Advanced Numerical Simulations for Kinetic Equations", Joint SIAM/RSME-SCM-SEMA Meeting Emerging Topics in Dynamical Systems and Partial Differential Equations. Barcelona (Spain), 31 May-4 June 2010.**
  This minisymposium was organized by Jingmei Qiu and myself. The organization consisted in inviting the participants, writing the program and chair the sessions.

- **Special session "Numerical techniques for the description of charged particles transport", 10th AIMS International Conference. Madrid (Spain). 7-11 July 2014.**
  I am the only organizer of this special session. The organization consists in inviting the participants, writing the program and chair the sessions.

### 1.8.3 Languages and informatic skills

**Languages:**

- Italian (native);
- English (Certificate of Proficiency in English, Cambridge, corresponding to C2, the highest level of the Common European Framework of Reference);
- French (DALF C2, the highest level of the Common European Framework of Reference);
- Spanish (Diploma de Español como Lengua Extranjera, nivel superior, Instituto Cervantes, corresponding to C2, the highest level of the Common European Framework of Reference);
- Catalan (EOI Barcelona Drassanes, C2, the highest level of the Common European Framework of Reference);
- Arabic (beginner);
- German (beginner).

**Informatics skills:**

- Environments: Linux (Ubuntu) and Windows.
- Software: LaTeX, Gnuplot, Office, Mathematica (beginner), Xfig.
- Languages: C++, C, Fortran 77 (beginner) et 90 (beginner), Bash.

# 2 Teaching activity

## 2.1 General comments

During my Ph.D. studies I did not acquire much teaching experience, as I gave only one course. I have been responsible for the practical work of the course on "Numerical integration of PDEs", of the final year of the degree in Mathematics at the Universitat Autònoma de Barcelona. During my staying in Austria I gave the practical work of the course "Hyperbolic Conservation Laws" at the Johannes Kepler Universität Linz, open to degree, master and Ph.D. students. During the Juan de la Cierva post-doctoral position, I gave the course "Mathematics II" of the first year of the degree in Chemical Engineering, in the Universitat de València.

## 2.2 Details of teaching activity

### 2.2.1 Numerical integration of PDEs (practical work)

**Degree:** mathematics, Universitat Autònoma de Barcelona (Spain).
**Year:** $4^{\text{th}}$ year (BAC+4).
**Academic year:** 2005-06.
**Hours:** 30.
**Program:** the course was dedicated to the analysis and implementation in language C of a solver for the heat equation in 1D.
**Persons in charge:** Josep Maria Modelo for the theoretical part, Francesco Vecil for the practical work.
**Personal task:** I was the sole responsible for the practical work of the course, of which I have decided the program and the final examination.

### 2.2.2 Hyperbolic conservation laws (practical work)

**Degree:** mathematics, Johannes Kepler Universität Linz (Austria).
**Year:** degree, master, Ph.D.
**Academic year:** 2009-10.
**Hours:** 14.
**Program:** the course has as a goal the analysis of consistency, convergence and stability, and the implementation in language C++ of the simplest finite differences schemele to solve the test case of linear advection.
**Persons in charge:** Massimo Fonte for the theoretical part, Francesco Vecil for the practical work.
**Personal task:** I have been the sole responsible for the practical work of the course, of which I have decided the program.

### 2.2.3 Mathematics II (theory and practical work)

**Degree:** chemical engineering, Universitat de València (Spain).
**Year:** $1^{st}$ (BAC+1).
**Academic years:** 2011-12, 2012-13.
**Hours:** 60.
**Program:** the course has as goals the teaching of partial derivatives, integration in two and three dimensions, methods for solving ODEs, series, Fourier series, complex variable functions.
**Persons in charge:** Francesco Vecil for the theory and the practical work.
**Personal task:** I have been the sole responsible for the course, of which I have decided the program and the examinations.

### 2.2.4 Numerical Analysis

**Degree:** ISIMA, Clermont-Ferrand (France).
**Year:** BAC+3.
**Academic years:** 2013-14.
**Hours:** 68 équiv. TD.

### 2.2.5 Integrals and solution of differential equations

**Degree:** Université Blaise Pascal, Clermont-Ferrand (France).
**Year:** L3 (Physics).
**Academic year:** 2013-14, 2014-15, 2015-16.
**Hours:** 26.

### 2.2.6 Numerical analysis

**Degree:** Polytech, Clermont-Ferrand (France).
**Year:** L2.
**Academic year:** 2013-14, 2014-15.
**Hours:** 14.

### 2.2.7 Series

**Degree:** Université Blaise Pascal, Clermont-Ferrand (France).
**Year:** L2 (Physique).
**Academic year:** 2013-14.
**Hours:** 28.

#### 2.2.8 Mathématiques Générales 2 (11MM22)

**Degree:** Université Blaise Pascal, Clermont-Ferrand (France).
**Year:** L1.
**Academic year:** 2013-14, 2014-15.
**Hours:** 30.

#### 2.2.9 Module A ou B Mathématiques (11MM11)

**Degree:** Université Blaise Pascal, Clermont-Ferrand (France).
**Year:** L1.
**Academic year:** 2014-15, 2015-16.
**Hours:** 85.

#### 2.2.10 Mathématiques (21MP31)

**Degree:** Université Blaise Pascal, Clermont-Ferrand (France).
**Year:** L2 (Physique).
**Academic year:** 2014-15, 2015-16.
**Hours:** 30.

#### 2.2.11 Harmonisation - Méthodes Numériques (41FM12)

**Degree:** Université Blaise Pascal, Clermont-Ferrand (France).
**Year:** M1.
**Academic year:** 2014-15, 2015-16.
**Hours:** 16.

#### 2.2.12 Mathematics applied to chemistry (21MM311)

**Degree:** Université Blaise Pascal, Clermont-Ferrand (France).
**Year:** L2.
**Academic year:** 2015-16.
**Hours:** 25.

#### 2.2.13 Numerical methods (31MM55)

**Degree:** Université Blaise Pascal, Clermont-Ferrand (France).
**Year:** L2.
**Academic year:** 2015-16.
**Hours:** 14.

# 3 Research activity

## 3.1 Participation to schools and conferences

- **1-5 September 2003:** New challanges in applied mathematics, Castro Urdiales (Spain).
- **13-21 August 2004:** ECMI Modelling Week, Lappeenranta, Finland, summer 2004.
- **29 September - 1 October 2005:** Journées EDPs et Applications, Communauté de Travail des Pyrénées, Université Paul Sabatier, Toulouse (France).
- **11-17 September 2006:** Quantum transport: modelling, analysis and asymptotics, CIME 2006, Cetraro (Italy).
- **09-14 July 2007:** DEASE Summer-school and Annual Meeting, Wolfgang Pauli Institut, Vienne (Austria).
- **08-10 October 2007:** International Workshop in Computational Electronics, University of Massachusetts, Amherst MA (USA).
- **15-21 November 2007**: Advanced school on numerical solution of partial differential equations. Barcelona (Spain).
- **14-21 June 2008:** COMSON International Summer School on Modelling and Optimization for the Design of Electronic Circuits and Devices, Baia Samuele, Sampieri (Italy).
- **15-19 September 2008:** SIMAI $9^{th}$ congress, Roma (Italy).
- **20-24 April 2009:** Quantum Systems and Semiconductor Devices: Analysis, Simulation, Applications, Peking University (Chine).
- **1-5 September 2009:** Comson International School for Modeling and Optimization in Micro- and Nano-electronics, Cetraro (Italy).
- **15-18 September 2009:** Summer School 2009: Modelling and simulation for magnetic fusion, Strasbourg (France).
- **17-21 May 2010:** PDEs in Engineering Nanoscience and Biology, Hammamet (Tunisia).
- **31 May-4 June 2010:** Joint SIAM/RSME-SCM-SEMA Meeting Emerging Topics in Dynamical Systems and Partial Differential Equations DSPDEs'10, Barcelona (Spain).

- **21-25 June 2010:** Joint SIMAI/SEMA conference on Applied and Industrial Mathematics, Cagliari (Italy).
- **19 July - 27 August 2010:** CEMRACS (Centre d'été de mathématiques et de recherche avancée en calcul scientifique) 2010: "Numerical models for fusion", Marseille (France).
- **8-12 October 2010:** PDEs in kinetic theories: kinetic description of biological models, Edinburgh (Scotland, United Kingdom).
- **14-18 March 2011:** Kinetic models of classical and quantum particle systems, held in memory of Naoufel Ben Abdallah at the Institut de Mathématiques de Toulouse (France).
- **19-25 September 2011:** 9th International Conference of Numerical Analysis and Applied Mathematics (ICNAAM 2011), held at G-Hotels, Halkidiki (Greece).
- **9-13 July 2012:** Analysis, Modeling and Simulation of Collective Dynamics from Bacteria to Crowds, International Center for Mechanical Sciences (CISM), Udine (Italy).
- **14-18 January 2013:**, WONAPDE 2013, Fourth Chilean Workshop on Numerical Analysis of Partial Differential Equations, Universidad de Concepción, Concepción (Chile).
- **9-13 June 2013**, CSASC 2013, held at Koper/Capodistria (Slovenia).
- **21-22 November 2013**, JERAA 2013, held at Saint-Étienne (France).
- **9-13 June 2014**, ECMI 2014, held in Taormina (Italy).
- **8-12 July 2014**, AIMS 2014, The 10th AIMS Conference on Dynamical Systems, Differential Equations and Applications, held in Madrid (Espagne).
- **15-19 September 2014**, PDE-MANS 2014, Workshop on PDEs: Modelling, Analysis and Numerical Simulation, held in Granada (Spain).

## 3.2 Collaborations with other institutions

- Center: Laboratoire MIP (Mathématiques pour l'Industrie et la Physique), Institut de Mathématiques de Toulouse, Université Paul Sabatier, Toulouse (France).
  Duration: 3 weeks.
  Year: 2004.

Topic: solvers for kinetic equations.
Collaborators: Naoufel Ben Abdallah.

- Center: Département de Mathématiques, Université de Nancy (France).
  Duration: 1 week.
  Year: 2005.
  Topic: implementation of a time-splitting WENO schem for laser-plasma interaction.
  Collaborators: Simon Labrunie.

- Center: Dipartimento di Matematica e Informatica, Università di Catania (Italy).
  Duration: 1 week.
  Year: 2006.
  Topic: implementation of a time-splitting WENO method for the Boltzmann-Poisson system for semiconductors.
  Collaborators: Armando Majorana.

- Center: Mathematics department, Johannes Gutenberg Universität, Mainz (Germany).
  Duration: 2 weeks.
  Year: 2006.
  Topic: Energy Transport models applied to transport problems.
  Collaborators: Stefan Holst.

- Center: Département de Mathématiques, Université de Lille (France).
  Duration: 1 week.
  Year: November 2006.
  Topic: numerical methods for macroscopic limits of kinetic equations.
  Collaborators: Thierry Goudon, Pauline Lafitte, José Antonio Carrillo.

- Center: Center of mathematical Sciences, Université de Cambridge (UK).
  Duration: 2 weeks.
  Year: 17/11/2008 - 29/11/2008.
  Topic: solvrs for chemotaxis problems.
  Collaborators: Peter Markowich, Klemens Fellner, Massimo Fornasier.

- Center: Institut de Mathématiques de Toulouse, Université de Toulouse (France).
  Duration: 3 days.
  Year: January 2009.
  Topic: solver for a coupled quantum/classical model for nanoMOSFETs.
  Collaborators: Naoufel Ben Abdallah, José Antonio Carrillo.

- Center: Departament de Matemàtiques, Universitat Autònoma de Barcelona (Spain).
  Duration: 3 weeks.
  Year: January 2009.
  Topic: kinetic solvers for swarming, flocking et milling problems.
  Collaborators: José Antonio Carrillo, José Alfredo Cañizo, Jesús Rosado.

- Center: Departamento de Matemáticas, Universidad de Granada (Spain).
  Duration: 1 month.
  Year: July 2009.
  Topic: parallel implementation of a deterministic solver for the sub-band Boltzmann-Schroedinger-Poisson model for nanoMOSFETs.
  Collaborators: María J. Cáceres, José Miguel Mantas, Carlos Sampedro, Andrés Godoy.

- Center: Département de Matemàtiques, Universitat Autònoma de Barcelona (Spain).
  Duration: 1 week.
  Year: November 2009.
  Topic: numerical simulation of collective behavior models.
  Collaborators: José Antonio Carrillo.

- Center: Laboratoire de Mathématiques de Toulouse, Université Paul Sabatier, Toulouse (France).
  Duration: 1 week.
  Year: November 2009.
  Topic: an AP (asymptotic-preserving) scheme for the simulation of sub-band models for nanoMOSFETs.
  Collaborators: Naoufel Ben Abdallah, Marie-Hélène Vignal.

- Center: Centre International de Rencontres Mathémqtiques, Luminy, Marseille (France).
  Duration: 6 weeks.
  Year: 19 July-27 August 2010.
  Topic: CEMRACS 2010: numerical models for fusion.
  Organizers: N. Crouseilles (INRIA Nancy-Grand-Est), H. Guillard (INRIA-Sophia Antipolis Méditerranée), B. Nkonga (Université de Nice et INRIA), E. Sonnendrücker (Université de Strasbourg et INRIA).

- Center: Newton Institute for Mathematical Sciences, University of Cambridge.
  Duration: 2 months.
  Year: 1 November 2010-22 December 2010.
  Topic: Partial Differential Equations in Kinetic Theories.

Organizers: J.A. Carrillo (Barcelona), S. Jin (Wisconsin) et P.A. Markowich (Cambridge).

- Center: IRMA (Institut de Recherche Mathématique Avancée), Université de Strasbourg.
  Duration: 1 week.
  Period: 28 February 2011-4 March 2011.
  Topic: Implementation of a Discontinuous Galerkin scheme for the guiding-center model.
  Collaborators: Nicolas Crouseilles (INRIA Strasbourg), Michel Mehrenberger (Strasbourg).

- Center: Departamento de Matemáticas, Universidad de Granada (Spain).
  Duration: 1 month.
  Year: July 2011.
  Topic: implementation of a deterministic Boltzmann-Schroedinger-Poisson sub-band model for nanoMOSFETs on a high-performance platform.
  Collaborators: María J. Cáceres, José Miguel Mantas, Carlos Sampedro, Andrés Godoy.

- Center: Departamento de Matemáticas, Universidad de Granada (Spain).
  Duration: 1 month.
  Year: June 2012.
  Topic: GPU version of the deterministic solver for partially-confined DG-MOSFETs.
  Collaborators: María J. Cáceres, José Miguel Mantas, Carlos Sampedro, Andrés Godoy.

- Center: Department of Applied Mathematics, Technical University of Munich, Garching-Munich (Germany).
  Duration: 1 week (17-21 December 2012).
  Year: December 2012.
  Topic: numerical analysis of the Cucker-Smale collective behavior model.
  Collaborator: Massimo Fornasier.

- Center: École Centrale Paris, Châteney-Malabry (France).
  Duration: 1 week (11-15 february 2013).
  Year: February 2013.
  Topic: Implementation of the 2D kinetic solver for an attractive/repulsive collective behavior model.
  Collaborator: Pauline Lafitte.

- Center: Universidad de Granada (Spain).
  Duration: 2 week.

Year: June 2013.
Topic: GPU version of the deterministic solver for partially-confined DG-MOSFETs.
Collaborator: María J. Cáceres, José Miguel Mantas, Carlos Sampedro, Andrés Godoy.

- Center: Departamento de Matemáticas, Universitad de Granada (Spain).
  Duration: 20 June-8 July 2014.
  Topic: parallelization on GPU of the subband solver for the Boltzmann-Schrödinger-Poisson system for nanoMOSFETs, and implementation of the surface roughness scattering phenomenon.
  Collaborators: José Miguel Mantas (Universidad de Granada), María J. Cáceres (Universidad de Granada), Carlos Sampedro (Universidad de Granada), Andrés Godoy (Universidad de Granada).

- Center: Departament de Matemàtica Aplicada, Universitat de València (Espagne).
  Duration: 14-25 July 2014.
  Topic: electrodynamic solver for the quasi-relativistic Vlasov-Maxwell solver.
  Collaborators: Pep Mulet Mestre, Antonio Baeza Manzanares.

- Center: Departamento de Matemáticas, Universitad de Granada (Spain).
  Duration: 2 weeks, 2015.
  Topic: parallelization on GPU of the subband solver for the Boltzmann-Schrödinger-Poisson system for nanoMOSFETs.
  Collaborators: José Miguel Mantas, María J. Cáceres.

## 3.3 Participation to research projects

- Qualitative properties of PDEs and diffusion equations.
  Funded by: DGI-MEC (Ministry for education and culture).
  Reference: MTM2005-08024.
  Period: 2005-2008.
  Main researcher: José Antonio Carrillo.

- Deterministic kinetic model for 2D MOSFET. Comparaison with Monte Carlo and parallel implementation on a cluster of PCs.
  Reference: CSD2006-0032 / FUT-C2-0041.
  Period: 01/12/2007-30/11/08.
  Main researcher: María J. Cáceres.

- Alta resolución y adaptatividad en modelos hiperbólicos y procesamiento de imágenes (High resolution and adaptivity in hyperbolic models and image pro-

cessing). Reference : MINECO MTM2011-22741 (Spanish Ministry of Economic Affairs and Competitiveness).
Period : 2012-2014.
Main researchers : Pep Mulet, Rosa Donat.

# 4 Résumé of the results

## 4.1 During the Ph.D. thesis

My main research activity developed with José Antonio Carrillo of the Universitat Autònoma de Barcelona (Spain). Under his supervision I developed numerical methods for the simulation of evolution problems described through hyperbolic and kinetic PDEs. This category of problems is traditionally treated through a Runge-Kutta time discretisation, coupled to finite differences or Galerkin discretisations for the phase-space, e.g. WENO (Weighted Essentially Non Oscillatory) methods for flux reconstruction. This strategy is robust and quite precise, but the constraint on the time-step, CFL condition, forces a large number of iterations, and increasingly larger proportionally to the grid refinement. It is with the aim of avoiding this constraint on the time-step that Strang splitting schemes become attractive. In exchange of a loss in the order-in-space (usually a second-order splitting is used instead of the third-order Total Variation Diminishing Runge-Kutta) and of some additional difficulties to a proper description of the asymptotic state, splitting methods allow for faster simulations, and are very effective for the description of transient states. Another advantage is the possibility of decomposing a complex problem into simpler problems, solving these last ones for separate and recombining them to approximate the solution of the complete problem. In particular, in the case of kinetic problems, the fundamental block is the solution of a one-dimensional advection problem, either linar or nonlinear. The first step of my work of thesis has, therefore, been the implementation and validation of a method for the one-dimensional linear advection, namely a semi-Lagrangian method based on reconstruction at the foot of characteristics. As interpolation we have chosen the PWENO (Pointwise WENO) scheme, a method which we have implemented at an arbitrary precision; nevertheless, for practical purpose, some routines have been optimized in order to minimise the computational times. The results have been validated through other methods in the literature and through the analysis of the scheme and comparisons with analytic solutions. Once the method has been validated in the simplest test case, it has been involved in increasingly complicated problems: first of all a two-dimensional test of a Boltzmann equation with a relaxation operator and a given potential, where the transport part is split from the collisional part (time splitting), the phase-space is split (dimensional splitting) and advections are linear. After that, the second test case has been a Vlasov-Fokker-Planck system, where the advection is nonlinear. The third test case has been a non-collisional Vlasov-Poisson system, where the advection stages have to be coupled to a solver for the electric field: we have implemented the classical test case of Landau damping, both linear and nonlinear, and the two-stream instability. The fourth and last test case used to validate the method has been a simple one-dimensional diode with collisions described through a relaxation operator. The results have been publushed in the **SIAM Journal on Scientific Computing**. During my Ph.D. thesis I went to Nancy to implement with Simon Labrunie a splitting method for a Vlasov-Maxwell system which describes the effect of a laser penetrating into a plasma. The code has given good results, but this work has not been published yet. During my Ph.D. we have, together with Armando Majorana of Catania, implemented a splitting method for a semiconductor in which the collisional operator described the scattering due to acoustic and optical phonons with multiple frequencies, after a one-week visit in Sicily. This work has given satisfactory results and has been published in **Communications in Computational Physics**. With the method we have proposed, adding as many scattering phenomena as we wanted has been easy. A work slightly separated from the line of the other ones in my thesis has been a collaboration we had with Thierry Goudon and Pauline Lafitte in Lille: we have worked on intermediate models between a simple kinetic equation with relaxation to a Gaussian and its diffusive limit the heat equation. First-order and second-order closures of the moment equations have been written and schemes for all these regimes have been written and implemented. The methods have been validated on typical test cases of this domain (the Su-Olson test) and the results have been published in the **Journal of Scientific Computing**. Before the defence of my Ph.D. thesis I obtained a pre-doctoral DEASE-Marie Curie fellowship to spend one year in Toulouse under the co-supervision of Naoufel Ben Abdallah: there, I have begun the implementation of a kinetic solver for the sub-band model describing a nanoscaled partially-confined Double Gate MOSFET: quantum effects are not neglectable anymore, stationary Schrödinger equations have to be solved in the confinement direction.

## 4.2 After the Ph.D. thesis

The research activity developed during my Ph.D. studies has been carried on after my Ph.D. defence.

With María J. Cáceres I have worked with a six-month post-doctoral position in Granada. There, I finished the first part of the work begun in Toulouse: an article with the methods for the computation of the eigenstates of the nanoscaled MOSFET, and simulations in the simplified case of one-valley band structure and relaxation as scatterings. This work has been published on the **Journal of Computational Physics**. Once the numerical schemes have been prepared in a simplified case, I have implemented a realistic model of interest for engineering, with three-valley silicon band-structure, non-parabolic bands, and a scattering operator with seven electron-phonon interaction phenomena. The goal of our code is to be a reference result for other less accurate but less costly models. In Granada works José Miguel Mantas, an informatic engineer specialist in parallel computing: with him we have reduced the computational times thanks to the parallelization on a cluster of CPUs. This work will be sent soon to the Journal of Scientific Computing. The parallelization on GPUs and adding the roughness as scattering phenomenon are works **in progress**.

Between October 2008 and September 2010 I had a post-doctoral position in Austria (RICAM, Linz): there, I started working with Massimo Fornasier on the simulation of swarming models, both at particle and kinetic level, this last one being its mesoscopic limit, needed when the number of agents is too large, like e.g. the migration of fish schools. In particular, with Massimo Fornasier we have focused on the Cucker-Smale model, which is a simple orientation model: the agents try to correct their velocities by observing their neighbours. These models have an interest in several domains in which a set of individuals converge to a uniform behaviour even if there is no leader. The paper concerning the numerical study of this model is being revised after the first reply from Physica D. On similar topics I also work with other people, namely Jesús Rosado and Pauline Lafitte: in this case the reference model tries to describe another characteristic of the behaviour of animal species, the fact of being social and wanting to stay close, but not too much, to other similars; this is modeled by an attraction/repulsion potential. This work has been accepted for publication in **Physica D**. The extension to the continuum 2D setting is **in progress**.

During summer 2010 I participated to the cemracs, in Luminy (Marseille), where with Nicolas Crouseilles and Michel Mehrenberger we have implemented a semi-Lagrangian Discontinuous Galerkin scheme for the simulation of the guiding-center model: the first part of the work describes how we solve the one-dimensional linear advection and how we pass to the two-dimensional case through a Strang splitting; the solver has then been validated with the classical test cases of Landau damping and bump-on-tail (published as a peer-reviewed **proceeding**); the second part of the work describes how we solve the 1D and 2D nonlinear advection, and the coupling to a Poisson solver in order to simulate the guiding-center model (**in progress**).

In end 2010 I started working with Armando Majorana of the University of Catania on the implementation of a Discontinuous Galerkin solver for the radiative transfert equation. He had the idea of treating separately the velocity-space and the position-space; the first one is treated by a low-order Discontinuous Galerkin method, which gives a system of PDEs in the other variables, system which, a priori, can be solved by any other method. This work is **in progress**.

Since 2011, with Pep Mulet of the University of Valencia, we are affording the application of an Adaptive Mesh Refinement (AMR) strategy to 1D and 2D semi-Lagrangian solvers for hyperbolic conservation laws: the idea is to use different resolution levels in the domain, depending on the features of the distribution function, thus using many discretization points only where needed and avoiding unnecessary time integrations. Our schemes have been successfully tested on the test cases of linear and nonlinear advection, nonlinear Landau damping, two-stream instability, swirling deformation flow and Kelvin-Helmholtz instabilities. The results have been published in the **Journal of Computational Physics**. We now aim at applying this solver to the simulation of laser-plasma interaction through the quasi-relativistic 1D Vlasov-Maxwell system (with Pep Mulet, Simon Labrunie, **in progress**).

After summer 2012, I have gone back to a work which has long been suspended, namely the simulation of a Vlasov-Maxwell model to describe the effect of a laser penetrating into a plasma; our goal is to test several novelties at the same time: a semi-Lagrangian splitting scheme for the quasi-relativistic problem, its coupling to an AMR strategy, and the transformation into AMR of a classical finite-differences Runge-Kutta scheme. This work is **in progress**.

# 5 Future plans

- *Simulation of the quasi-relativistic Vlasov-Maxwell model for laser-plasma interaction, through a semi-Lagrangian Strang-split AMR scheme.*

  Adaptive Mesh Refinement (AMR) strategies can be used to speed up simulations in which there are zones of the domain that do not carry essential information and that can be thus given less resolution than others. By now, with Pep Mulet of the University of Valencia, we have implemented a 1D semi-Lagrangian solver, extended to 2D thanks to the Strang splitting, we have coupled it to a fast solver (FFTW) for the Poisson equation, and we have tested it against classical, academic test cases (results published on the **Journal of Computational Physics**). Several features of this solver can still be improved: the use of resolution-adapted time steps; the use of a different solver for the advection, namely in order to improve the conservation properties; improve the approximation of Jacobian by higher-order schemes inside the characteristic-based formula for the the time integration.

  We wish now to apply our solver to a problem of interest in the field of fusion research: the laser-plasma interaction, described by a 1D Vlasov-Maxwell model. Fixed-mesh schemes based on finite differences and a Runge-Kutta time integration have already been implemented by Simon Labrunie. We wish now to provide three novelties: coupling the *leap-frog* Yee scheme for the computation of the Maxwell part to a semi-Lagrangian Strang-split WENO scheme for the transport part, so as to be allowed to use larger time steps; coupling this method to an AMR strategy; using the AMR strategy also for the finite-differences scheme. At the end we aim at an empirical hint about the most effective way of integrating the quasi-relativistic Vlasov-Maxwell system. This work is **in progress** (with Simon Labrunie and Pep Mulet).

- *Deterministic simulation for a partially-confined DG-MOSFET through the Boltzmann-Schrödinger-Poisson model.*

  The MOSFET is the fundamental block of any electronic device. The technological development produces smaller and smaller transistors, and now sizes have been reached for which quantum effects cannot be neglected anymore, most of all because of the confinement in the transversal direction. Nowadays' solvers are usually Monte Carlo, which is noisy and provides unreliable information in the zones with a low electron density, or macroscopic, which lack precision. This is why it is interesting to have a deterministic solver, whose goal is to provide reference results even if it is computationally costlier than other methods. In 2006 I have started working on this topic in Toulouse with Naoufel Ben Abdallah (my thesis' co-supervisor). The numerical methods for the computation of the confinement have been written (the results are published on the **Journal of Computational Physics**), and a big implementation effort has been made. In this first stage we have used Cartesian coordinates for the wave vector and a semi-Lagrangian splitting scheme for the time integration. We have now improved the solver in several directions: seven electron-phonon interaction phenomena; ellipsoidal coordinates for the wave vector in order to better integrate the scattering operator; Runge-Kutta time discretization coupled to a finite-differences WENO scheme, which is better suitable for ellipsoidal coordinates for the wave vector; MPI-parallel code on a cluster of CPUs; comparison to Monte Carlo. The work up to here is going to be sent soon to the **Journal of Scientific Computing**. Apart from that, we are also improving the model by taking into account the surface roughness phenomenon and we are developing a parallel code on the GPU (through CUDA libraries), with the ultimate goal of developing an open computational platform (**in progress**). This work is being developed with María J. Cáceres (mathematician), José Miguel Mantas (informatic engineer), Carlos Sampedro, Andrés Godoy et Francisco Gámiz (electronic engineers), all of them from the University of Granada.

- *Implementation of a semi-Lagrangian discontinuous-Galerkin (DG) scheme for the guiding-center model.*

  The guiding-center model is of interest in the field of nuclear fusion. DG schemes allow for an improvement of the resolution thanks to a local refinement, which gives no constraint on the time stepping and allows for a parallelization of the code. During cemracs 2010 we have, with Nicolas Crouseilles and Michel Mehrenberger, started implementing this kind of solvers, and we have tested these methods for the Vlasov-Poisson model, with a Strang-split phase space. These results are published as (peer-reviewed) **proceeding**. The difference in the case of the guiding-center model is that the advection is non-constant (with respect to the advected variable) and that the field is 2D. The state-of-the-art is the following: we can solve the 2D Poisson equation on a DG discretization, we can solve the non-constant advections and therefore we can simulate the guiding-center model. Still, our strategy should be compared to those in the litterature and the *divergence-free* condition should be numerically imposed. This work is **in progress**.

- *Numerical analysis of collective-behavior models.*

  Collective-behavior models aim at describing situations in which a certain amount of agents achieve a uniform behavior even if there is no leader, like e.g. bird flocks, the development of languages in primitive societies, the averaging of prices in stock exchanges. With Massimo Fornasier, we have worked on the numerical analysis of the Cucker-Smale model, which is a simple orientation model: the "birds" modify their velocities by copying the direction of their neighbors. The paper with the results is being revised at **Physica D**. Our work up to now mainly concerns the results in the discrete context; still, we wish to perform an exaustive numerical study in the continuum setting, a work which is **in progress**. With Pauline Lafitte and Jesús Rosado, we have worked on a different kind of model, of the attractive/repulsive category; the numerical study on the 3D discrete case and the 1D continuum case has been published in **Physica D**, and the extension to the 2D continuum setting is **in progress**.

- *Developement and implementation of a Discontinuous Galerkin scheme for the radiative transfert equation.*

  The radiative transfert equation has arisen to a new interest in the field of medical analyses. Armando Majorana had the idea of treating the kinetic equations in a quite simple way: first of all we integrate in velocity through a first order Discontinuous Galerkin discretization, then a set of kinetic equations has to be solved, which can be realized with any method, for instance with a Discontinuous Galerkin method coupled to a Runge-Kutta time discretization for the sake of coherence. We obtain a quite simple scheme which we want to implement and test on benchmarks in the literature. This work is **in progress**.

- *Spectral methods for the integration of scattering phenomena for the Boltzmann equation.*

  When, in the Boltzmann equation, the scattering operator is essentially given by a sum of Dirac masses, a spectral method could be used. María J. Cáceres and Clément Mouhot started writing the numerical scheme some years ago. The idea seems interesting because no numerical cost would be added to the traditional schemes, nevertheless improving their precision.

- *Analysis and numerical study of the plasma oscillations.*

  When a bias is applied to a positive-doped transistor, the holes try to oppose the electrons' displacement. This leads to oscillations (before the system stabilizes towards an equilibrium) which are all the more evident as the device's size becomes smaller and the applied bias large. This phenomenon, in principle, does not depend on the quantum effects nor on the scattering operator, but essentially on the self-consistent electric field given by the Poisson equation. With María J. Cáceres, we wish for a better understanding of this aspect of the diodes by developing an analysis and a numerical study of different models of increasing complexity: 1D Vlasov-Poisson, 1D Boltzmann-Poisson with plain relaxation, etc., up to partially-confined devices taking into account electron-phonon interaction and surface roughness.