Research Report

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Contents

1 Research Topics 2

2 Research Contributions 2
  2.1 Articles .......................................................... 2
  2.2 Submitted articles ............................................. 6
  2.3 Other refereed contributions ................................. 6
  2.4 Research reports ............................................... 7
  2.5 Editorial tasks ................................................ 8
  2.6 Long term funded invitations (Since 2010) ............... 8
  2.7 Software ........................................................ 8
  2.8 Industrial Projects ............................................ 9
  2.9 Seminars & Workshops since Aug. 2005 (Arrival to Canada) ................. 9

3 Other Evidence of Impact and Contributions 11
1 Research Topics

List of research topics: partial differential equations, numerical analysis, mathematical and computational physics.

- Microlocal and pseudodifferential analysis of domain decomposition methods for quantum wave linear and nonlinear equations. Analysis of Schwarz Waveform Relaxation methods: [A34], [A39], [A40], [A41], [A43], [A45], [A46], [A48].

- Microlocal analysis-based Absorbing Boundary Conditions for relativistic and nonrelativistic wave equations (Schrödinger, Dirac): [A33], [A13], [A42].

- Mathematical relativistic quantum physics and Weyl-Titschmarsh-Kodaira theory: pair-production, Schwinger’s effect, Dirac equations: [A27], [A26], [A24], [A22]. Gauge theory: [29].

- Mathematical modeling in multiscale nonperturbative nonlinear optics, filamentation-laser and attosecond science, Maxwell-Schrödinger and Liouville equations, applied spectral theory: [A38], [A36], [E2], [A35], [A28], [A21], [A23], [A17], [A11], [A9], [A7].

- High order and parallel methods in quantum physics for Dirac, Schrödinger equations: Galerkin methods, high order B-splines, balanced-operators, High order splitting methods. [A37], [A31], [A20], [A19], [A18], [A44].


- Derivation and analysis of non-diffusive finite volume methods for hyperbolic systems of conservation laws: reservoir technique. [A12], [A10], [A1].

- High performance Computing in computational physics, MPI/C++, Distributed parallel computing. [A37], [P10], [P7], [A9]

2 Research Contributions

2.1 Articles


## 2.2 Submitted articles


## 2.3 Other refereed contributions


2.4 Research reports


2.5 Editorial tasks

[E3] Member of Editorial Board. Advances in Mathematical Physics (2015-to date)


2.6 Long term funded invitations (Since 2010)

- Invited Researcher at KITP (Kavli Institute for Theoretical Physics) at University of California at Santa Barbara (2 weeks), April 2015.

- Invited Professor in the Mathematics department at the University of California at Santa Barbara (1 month), Jan. 2015.

- Invited Researcher at the KITP at University of California at Santa Barbara (1 month), Sept. 2014.

- Invited Professor in the Applied Mathematics department, Université de Grenoble, France (2 months), May-June 2011.

2.7 Software

Some software that I have (co-)developed.


[S3] Development of a C++ parallel quantum chemistry simulation code at the University of Minnesota (2002-2003). The code is installed at the Minnesota Supercomputing Institute and computes optical spectra of molecules.
Implementation of new numerical methods for electronic structure calculation in Abinit (www.abinit.org), (2002). We proposed a new $O(N)$ method particularly efficient at high temperatures and for big molecules, instead of usual $O(N^3)$ methods.

Participation in the development of the Oriented-Object code TRIO_U (2001), at the French Atomic Energy Center (CEA). I implanted a new 3d numerical implicit finite volume scheme for simulation of two phase flows inside the core of power stations.

2.8 Industrial Projects

- MITACS cluster-project (granted). Name of the company: general fusion (British Columbia). Modeling and computations for MTF-based nuclear reactor (HQP: 2 PDF, 1PhD), $133,000, 2010-12.

2.9 Seminars & Workshops since Aug. 2005 (Arrival to Canada)

- Seminar of Applied Mathematics at Carleton University, Ottawa, Feb. 2006.
- Seminar of Applied Mathematics at Université de Montréal, Montréal, April 2006.
- Seminar of Theoretical Chemistry, University of Sherbrooke, Sherbrooke, April 2006.
- Seminar of Applied Mathematics at Concordia University, Montréal, Dec. 2006.
- Workshop on ultrafast lasers, Laval University, March 2007.
- Mathematics seminar, Laval University, June 2007.
- 76th ACFAS conference, Québec City, May 2008.


• Seminar of Applied Mathematics, Ottawa University, Nov. 2008.

• CMS Winter Meeting: Session Applied PDEs, Ottawa, Dec. 2008.


• Seminar Mathematics, Carleton University, Dec. 2008.

• Seminar Physics & Chemistry, Trent University, March 2009.

• Workshop on Computational Hyperbolic Systems, Fields Institute, April 2009.

• CAIMS Meeting 2009, University of Western Ontario, June 2009.

• Workshop on Quantum Dynamic Imaging, CRM, Nov. 2009.


• Physics Seminar, Commissariat à l’Energie Atomique (France), June 2011.

• Applied Mathematics seminar, Ecole Normale Supérieure de Cachan (France), June 2011.

• Applied Mathematics seminar, Université de Chambéry (France), June 2011.


• 4th Workshop on Industrial Mathematics. Coordinator for INO project, Montréal, Aug. 2011.

• Applied Mathematics seminar, State University of New York at Buffalo, Feb. 2012


• Canadian Applied and Industrial Mathematics Society Meeting, Québec City. June 2013.


• International Workshop on mathematical methods and models in laser-filamentation, Montréal, March 2014.

• Applied Mathematics seminar, University of Ontario Institute of Technology, April 2014.

• KITP at University of California Santa Barbara, Aug. 2014.

• University of Ottawa, Physics Seminar, January 2015.

• Applied Mathematics seminar, University of California Santa Barbara, Jan. 2015 (2 talks).


• CRM Networking Industrial Workshops - Photonics, Centre de Recherches Mathématiques, Montréal, Sept. 2015.


• Symposium Molecules & Laser Fields, Orford, May 2016.

• AIMS-2016, Orlando, June 2016.

• KI-NET conference, University of California Santa Barbara, Nov. 2016.

• CAIMS Conference, University of Alberta, June 2016.

• Quantum and Kinetic Problems, CSRC, Beijing, June 2017.

• From Quantum Dynamics to Quantum Information, BIRS/CMO, Mexico, August 2017.

3 Other Evidence of Impact and Contributions

Co-organizer of Conferences and Workshops


• Durham Regional Youth Science Foundation Science Fair (chair), Oshawa, April 2008.


• Durham Regional Youth Science Foundation Science Fair (chair), Oshawa, April 2009.


• Seventh Montréal Scientific Computing Days, Montréal, May 2013.


• International Workshop on Mathematical Modeling and Analysis of Filamentation (Centre de Recherche Mathématiques, Montréal), March 2014.


• Banff/CMO. From Quantum Dynamics to Quantum Information Theory, August 2017.

• DDM-25: International Conference on Domain Decomposition Methods, St-John, Canada, July 2018.

Referee tasks


• Reviewer for NSERC (Collaborative Research and Development program), 2013.


• Reviewer for NSERC (I2I program), 2017.

Defense committee: Reviewer


• Master thesis defense of L. Charette at Ottawa University. Lattice symmetry breaking perturbation for spiral waves, June 2013.


• PhD thesis defense of H. Beauchesne at Carleton University. Possible avenues in supersymmetry and naturalness. August 2016.


• MSc thesis defense of X. Chen at Carleton University. Cooperative Linear-Quadratic Mean Field Game Control and Hamiltonian Matrix Analysis. April 2017.


Research Grants and Fellowship

• NSERC Discovery Grant : $15,000/year, GSC Pure and Applied Maths B 337, 2013-2018.

• Co-applicant (with 6 others) of a granted Research Tools Instruments (NSERC), $46,068, (2012).
• Fields Institute Funds for Post-Doc. Fellowship ($12,500) (2011-2012).

• CRM/ISM Funds to hire a Post-Doc. Fellowship ($7,500 shared with Prof. A. Bandrauk), (2012)

• Invited Professor (May-June 2011). Applied Mathematics Department at Université Joseph Fourier - Grenoble I (France). €7,500.

• P.I. of a granted MITACS Project (cluster): 2 post-docs, 1 PhD, Travel Subsidy Award. Collaboration with the company General Fusion (Vancouver), and Prof. M. Laforest (Ecole Polytechnique de Montréal), $133,000 over 2 years, 2010/2012.

• Research Grant as SHARCNET siteleader: $8,000 / year, 2008/09.

• CRM/ISM Funds to hire a Post-Doc. Fellowship ($20,000 shared with Prof. A. Bandrauk).

• Participation (P.I. in Ontario) to a granted $2,377,000 CFI/NFI project on Dynamic Imaging and Visualization: iMOVI, 2009 (Participation withdrawn due conflict with Compute Canada policy).

• CRM-ISM Postdoctoral Fellowship (Montréal), 2005-2007.

• AUF (Agence universitaire de la Francophonie) Granted project on the Shallow Water Equations (collaboration Canada/France/Maroc): €20,000, 2006.

• Supercomputing Institute Research Scholarship (Minnesota Supercomputing Institute, University of Minnesota), 2002.


Current Students

• M. Lytova, PhD.

• D. Charles, Honours.

Past Students

• T. Hof McNeil, MSc.

• F. Fillion-Gourdeau, Post-Doc., co-supervision with A. Bandrauk.

• F. Hou, Research Assistant.

• F. Albeshree, MSc in Applied Maths (Course).

• A. Capuano, Honours Student (Thesis not defended).
• K. Lyon, Summer Student (2012).
• R. Arteaga, Research Assistant/ Honours Student (2011-2012).
• H. Rizq, MSc in Applied Maths (2014).
• M. Kazeminia, PhD Student (registered at Ecole Polytechnique de Montréal), co-supervision with Prof. M. Laforest (2010-2012).
• X. Lavocat-Dubuis, Post-Doc. (2010-2011)
• E. Zaoui, CRM/ISM Post-Doc., partially funded (50%) by the Centre de Recherches Mathématiques (2009-2010).
• N. Chalmers, Honours/MSc Student then Research Assistant, Carleton University (2010).
• +3 Honours students at UOIT (2008,2009).
• +3 Master students, Université Paris-Sud-Orsay (2002-2005).