

**Curriculum Vitae (April 15, 2011)**  
**Lisa Jeffrey**  
**Department of Computer and Mathematical Sciences**  
**University of Toronto at Scarborough**  
**1265 Military Trail**  
**Scarborough, ON M1C 1A4**

**A. Biographical Information**

**1. Personal**

Citizenship: Canadian

Home address: 21 Shaftesbury Ave. #106, Toronto, ON M4T 3B4

Home telephone: 416-964-1513

**2. Degree:**

Ph.D. Oxford University, 1992  
Supervisor: M.F. Atiyah  
Thesis title: On some aspects of Chern-Simons gauge theory

M.A. Cambridge University (Trinity College), 1988

A.B. Princeton University, 1986

**3. Employment:**

*3a. Positions:*

1997 – University of Toronto, Professor (on leave of absence 1997-8)

1996-1997 Institute for Advanced Study, Member (School of Mathematics)

1996-8 McGill University, Associate Professor (tenured)

1995-6 McGill University, Assistant Professor

1992-7 Princeton University, Assistant Professor (on leave of absence 1995-7)

1993-6 NSF Mathematical Sciences Postdoctoral Research Fellowship, DMS-9608029

1992-3 Downing College, University of Cambridge, Research Fellow

1991-92 Institute for Advanced Study, Postdoctoral Fellow

*3b. Visiting positions:*

May 2003, Harvard University, Visiting Professor (I was invited to spend one term at Harvard, but could go for only one month because I had three graduate students nearing the end of their Ph.D. theses)

2003, invited to spend one year at Göttingen University (declined)

September 1997, Univ. Paris-Sud (Orsay), Visiting Professor (Professeur Invité).

September 1996-April 1997, Institute for Advanced Study (Princeton, NJ), member, School of Mathematics; participated in the IAS Program on Quantum Field Theory.

July 1997, IAS/Park City Mathematics Institute, lecturer (one of eight principal lecturers in graduate summer school on Symplectic Geometry).

July 1995, University of Adelaide, Department of Mathematics, visiting lecturer.

July 1995, Odense University, Summer School on Geometry and Physics (Danish Academy of Sciences), lecturer.

May-June 1995, Institut Henri Poincaré, Centre Emile Borel (Paris, France) and Université Paris VII, visiting professor (Professeur Invité).

March-April 1993, Mathematical Sciences Research Institute (Berkeley, California), visiting member.

July 1991, NSF Regional Geometry Institute (Park City, Utah), postdoctoral participant.

May-June 1991, Mathematical Sciences Research Institute (Berkeley, California), visiting member.

#### 4. Honours:

2007 Royal Society of Canada – Fellow (inducted November 2008)

2004 E.W.R. Steacie Memorial Fellowship (NSERC)

2002 Principal's Research Award (UTSC) This award is based on research excellence and provides the equivalent of one half course teaching relief.

2002 Coxeter-James Lectureship

The Coxeter-James Lectureship is awarded annually by the Canadian Mathematical Society to recognize outstanding research by a young mathematician. I delivered this lecture at the Winter 2002 CMS meeting.

2001 Krieger-Nelson Prize

The Krieger-Nelson Prize is given annually by the Canadian Mathematical Society to recognize outstanding research by a woman mathematician.

2000 McLean Award (University of Toronto)

1999-2004 Premier's Research Excellence Award

1997-99 Alfred P. Sloan Foundation Fellowship.

1996-7 Aisenstadt Prize (CRM, Montréal).

This prize is awarded to young Canadian mathematicians (less than 7 years beyond the Ph.D.) for excellence in research. In 1996-7 two prizes were awarded, one to Henri Darmon and the other to myself.

1993 (January) Taniguchi Foundation Symposium (Low Dimensional Topology and Topological Field Theory) participant

1990 Smith's Prize (Group II) (Cambridge University).

These prizes are awarded to mathematics graduates of Cambridge University, on submission of a dissertation normally written in the second year following completion of the Cambridge University undergraduate mathematics sequence. Prizes are ranked in groups I through VI, with group I being the highest ranking; in that year, a total of approximately twenty prizes were awarded, with one awarded in group I and two (including my own) in group II.

1987 Rouse Ball Mathematical Essay Prize (Trinity College, Cambridge).

These prizes are awarded to Trinity College undergraduates on submission of a short expository dissertation on a mathematical topic. My dissertation (of approximately 30 pages) obtained the highest ranking of any submitted in that year.

1986 Phi Beta Kappa Society

1986 Phi Beta Kappa Prize (for highest academic standing in graduating class, Princeton University)

1986 Princeton University valedictorian

1985 and 1986 Kusaka Memorial Prize in Physics (Princeton University)

1984 and 1985 NSERC (Canada) Undergraduate Summer Research Award

1984 Freshman First Honor Prize (Princeton University)

## 5. Professional Affiliations and Activities

(i) *Professional societies:*

Member: American Mathematical Society, Canadian Mathematical Society, Association for Women in Mathematics.

(ii) *Refereeing:*

Referee for *Adv. Math.*, *Archiv der Math.*, *Ann. Math.*, *Ann. Scient. Ecole Normale Sup.*, *Ann. Inst. Fourier*, *Canad. J. Math.*, *Canad. Math. Bull.*, *Commun. in Analysis and Geom.*, *Commun. Math. Phys.*, *Comptes Rendus*, *Duke Math. J.*, *Experimental Math.*, *Internat. J. Math.*, *Invent. Math.*, *J. Amer. Math. Soc.*, *J. Funct. Anal.*, *J. Diff. Geom.*, *J. Geom. Phys.*, *J. Reine Angew. Math.*, *J. Topology*—*Lett. Math. Phys.*, *Manuscripta Math.*, *Math. Annalen*, *Mathematical Research Letters*, *Mathematical Physics*, *Analysis and Geometry*, *Pacific J. Math.*, *Proc. Edin. Math. Soc.*, *Topology*, *Trans. Amer. Math. Soc.*, and for several articles in refereed conference proceedings and one monograph submitted to Lecture Notes of the London Mathematical Society.

Referee for NSERC grant proposals, committees 29 (General Physics), 336 (Pure Mathematics) and 337 (Applied Mathematics).

Referee for NSF grant proposals, Division of Mathematical Sciences (Program in Geometric Analysis, Program in Topology and Foundations, Focused Research Groups).

Referee for EPSRC grant proposals

Referee for Marsden Foundation (New Zealand)

Referee for Hong Kong Research Grants (2010)

Referee for Australian Research Grants (2009)

Asked to referee a proposal for Netherlands Organisation for Scientific Research and Netherlands Foundation for Fundamental Research on Matter (declined)

(iii) *Editing of journals:*

Editor for *ISRN Mathematics* (starting March 2011)

Editor for *Transactions of the American Mathematical Society* (February 2001- January 2005; extended to January 2009)

Invited to become Editor for *Canad. J. Math.* (December 2006 – December 2011) (declined).

Asked to serve on NSERC Grant Selection Committee, 336 (requested to postpone this until 2006-7 – by 2006, was informed that NSERC no longer required an additional member of GSC 336)

Asked to serve on NSF review panel to review grant applications, 2006 (declined)

(iv) *Editing of monographs*: Member of Editorial Advisory Board for *Encyclopedia of Mathematical Physics* (Oxford) (since January 2003).

## **B. Academic History**

### **6. Research Endeavours**

My current research uses techniques from pure mathematics (notably symplectic geometry, the natural mathematical framework for classical mechanics) to prove results obtained by theoretical physicists using the methods of quantum field theory. In my doctoral thesis (under the supervision of Michael Atiyah) I provided a mathematically rigorous proof of results on the asymptotics of the three-manifold invariants of Witten and Reshetikhin-Turaev which Witten had conjectured based on his approach to these invariants using quantum field theory. In recent joint work with Frances Kirwan I have proved formulas of Witten which encode the structure of the cohomology ring of the moduli space of holomorphic vector bundles on a Riemann surface: the main technique used is a method from symplectic geometry and equivariant cohomology known as nonabelian localization, which Kirwan and I developed in our initial paper.

In joint work with Jonathan Weitsman I have studied these moduli spaces using techniques from symplectic geometry (the theory of Hamiltonian group actions): these methods endow the moduli spaces with Hamiltonian flows, in some cases leading to a structure of integrable system on them, and yielding a very transparent description of the formulas for their symplectic volumes.

I collaborated with Megumi Harada, Tara Holm and Augustin-Liviu Mare to prove that the level sets of the moment map for the torus action on the based loop group are connected.

I have continued to collaborate with Frances Kirwan, Young-Hoon Kiem and Jonathan Woolf on singular symplectic quotients (including moduli spaces) and hyperkähler quotients. I have collaborated with Augustin-Liviu Mare on cohomology of symplectic quotients and on convexity of the real locus of spaces with Hamiltonian group actions.

In collaboration with Augustin-Liviu Mare (since 2009) we have studied the real locus of the based loop group and other examples.

In collaboration with Megumi Harada and Paul Selick (since 2010) we have studied the K-theory and the equivariant K-theory of the based loop group.

### **6b. Research Awards**

1. 2011–2016 NSERC Discovery Grant (\$42,000 per year for 5 years)
2. 2006–2011 NSERC Discovery Grant (\$40,000 per year for 5 years)

3. 2004 – Connaught Fund, Support for International Symposia and Colloquia: \$7,500 (for the Workshop on Forms of Homotopy Theory: Elliptic Cohomology and Loop Spaces, Fields Institute, September 2004)
4. 2004 –2006 E.W.R. Steacie Memorial Fellowship (NSERC). \$90,000 per year for two years to UTSC (salary replacement) plus \$53,000 per year for two years (Steacie Supplement), NSERC.
5. 2003 –2007 Leadership Support Initiative (NSERC), July 1, 2003- June 30, 2007, \$42,000 per year. Principal investigator (co-applicants Yael Karshon, Boris Khesin and Eckhard Meinrenken).
6. 2002– 2006 NSERC Discovery Grant (\$42,000 per year for 4 years)
7. 2002 – Principal’s Research Award (UTSC) This award is based on research excellence and provides the equivalent of one half course teaching relief.
8. 2000 – McLean Award (\$100,000 to be used over the period 2000- 2007)
9. 1999 – Premier’s Research Excellence Award (\$100,000 to be used over the period 1999-2004)
10. 1999 – Connaught Fund start-up grant (\$10,000)
11. NSERC operating grant (\$30,800 during 1998-9, \$32,340 during 1999-2002)
12. 1997– Alfred P. Sloan Foundation Fellowship (US \$35,000, to be used over the two years 1997-1999, period of use extended to September 2001)
13. 1997-2000 FCAR team grant (with S.T. Ali, S. Boyer, J. Harnad, J. Hurtubise, A. Joyal, N. Kamran, F. Lalonde), \$120,000 p.a.
14. 1995- NSERC Women’s Faculty Award (\$30,500 p.a. for three years: my application for renewal for two further years for use at McGill University was successful)
15. 1995-8 NSERC Operating Grant (\$18,600 p.a. for three years)
16. 1995-8 FCAR Nouveau Chercheur grant (\$14,000 p.a. for three years)
17. 1995-6 FCAR equipment grant (\$8,418)
18. 1994- participant in USA National Science Foundation grant DMS-9401714 (W. Browder, W.-C. Hsiang), \$1,500 US (for travel expenses).
19. 1993-6 USA National Science Foundation Mathematical Sciences Postdoctoral Research Fellow, grant DMS-9306029. (\$33,000 US per year for three years)
20. 1992-93 University of Cambridge (Downing College) - Research Fellow in Mathematics.
21. 1991-92 Institute for Advanced Study, Princeton, NJ - Member, School of Natural Sciences.
22. 1989-90 Wolfson College (Oxford) Graduate Scholarship
23. 1988-91 (USA) NSF Graduate Fellowship: Oxford University
24. 1988-91 Overseas Research Scholarship (UK): Oxford University
25. 1987-8 De Lancey Scholarship (Trinity College, Cambridge)
26. 1986-88 Marshall Scholarship (British Council): Cambridge University

## C. Scholarly and Professional Work

### 7. Refereed Publications

#### 7a. articles

1. (with Brendan McLellan) Eta invariants and anomalies in  $U(1)$  Chern-Simons theory,

- (arXiv:1004.2913). To appear in Proceedings of *CS Theory: 20 Years After* (refereed conference proceedings), AMS/IP Studies in Advanced Mathematics, 21 pages, accepted May 2010.
2. (with T. Baird and P. Selick) The space of commuting  $n$ -tuples in  $SU(2)$ . *Ill. J. Math.*, to appear. (Accepted 2010)
  3. Intersection pairings for singular moduli spaces. 11 pages. To appear in *Grassmannians, Moduli Spaces and Vector Bundles* (Clay Mathematics Institute vol. 10). (Accepted 2009)
  4. Connectedness of Level Sets of the Moment Map for Torus Actions on the Based Loop Group. In *A Celebration of the Mathematical Legacy of Raoul Bott* (R. Kotiuga, editor), CRM Proceedings vol. 50, AMS 2010, 181-184.
  5. (with Young-Hoon Kiem and Frances Kirwan) On the cohomology of hyperkähler quotients. *Transformation Groups* **14** no. 4, 801-823 (2009).
  6. (with Augustin-Liviu Mare) Real loci of based loop groups. *Transformation Groups* **15** no. 1, 134-153 (2010).
  7. (with Brendan McLellan) Non-abelian localization for  $U(1)$  Chern-Simons theory. Accepted December 2008. To appear in Proceedings of Conference on Geometric Aspects of Analysis and Mechanics (in honour of the 65th birthday of Hans Duistermaat). Birkhäuser, p. 173-186.
  8. Connectedness of level sets of the moment map for torus actions on the based loop group. In Proceedings of the Conference on the Legacy of Raoul Bott, CRM. CRM Proc. Lecture Notes **50**, AMS, 2010, 181–184.
  9. (with David Klein) Goldman flows on the Jacobian. *J. Geom. Phys.* **59** (2009) 32–34.
  10. (with Megumi Harada, Tara Holm and Liviu Mare) Connectivity properties of moment maps on based loop groups. *Geometry and Topology* **10** (2006) 1607-1664.
  11. (with Joon-Hyeok Song) Intersection numbers in quasi-Hamiltonian reduced spaces. *Pure and Applied Mathematics Quarterly* **2** (2006) 837-865 (Special Issue in Honor of Robert MacPherson, Part 1 of 3).
  12. (with Y.-H. Kiem, F. Kirwan, J. Woolf) Intersection pairings on singular moduli spaces of vector bundles over a Riemann surface and their partial desingularisations. *Transformation Groups* **11** (2006) 1-56.
  13. Hamiltonian group actions. *Encyclopedia of Mathematical Physics*, Encyclopedia of Mathematical Physics, eds. J.-P. Francoise, G.L. Naber and Tsou S.T. Oxford: Elsevier, 2006, volume 2, p. 600-606 (2006).
  14. (with J. Hurtubise and R. Sjamaar) Moduli of framed parabolic sheaves. *Annals of Global Analysis and Geometry*, **28** (2005), no. 4, 351–370.
  15. (with Nan-Kuo Ho) The volume of the moduli space of flat connections on a nonorientable surface. *Commun. Math. Phys.* **256** (2005), 539–564.
  16. (with Mark Hamilton) Symplectic fibrations and Riemann-Roch numbers of reduced spaces. *Quart. J. of Math.* **56** (2005), no. 4, 541–552.
  17. (with A.-L. Mare and J. Woolf) The Kirwan map, equivariant Kirwan maps, and their kernels. *J. Reine Angew. Math.*, **589** (2005) 105–127.

18. (with J. Hurtubise and R. Sjamaar) Group-valued implosion and parabolic structures. *Amer. J. Math.* **128** (2006), no. 1, 167–214.
19. (with Mikhail Kogan) Localization theorems by symplectic cuts. *The Breadth of Symplectic and Poisson Geometry* (Festschrift in Honor of Alan Weinstein), J. Marsden, T. Ratiu, editors, Birkhäuser *Progress in Mathematics* **232** (2005) 303-326.
20. (with A.-L. Mare) Products of conjugacy classes in  $SU(2)$ . *Can. Math. Bull.* **48** (2005) 90-96.
21. Flat connections on oriented 2-manifolds. *Bull. London Math. Soc.* **37** (2005) 1-14.
22. (with R. Goldin and T. Holm) Distinguishing the Chambers of the Moment Polytope. *J. Sym. Geom.* **2** (2003) 109-132.
23. (with A.-L. Mare) The kernel of the equivariant Kirwan map and the residue formula. *Quart. J. Math.* **54** (2003), no. 4, 435–444.
24. The residue formula and the Tolman-Weitsman theorem. *J. für die reine u. angew. Mathematik*, **562** (2003), 51–58.
25. (with Y. Kiem, F. Kirwan and J. Woolf) Cohomology pairings on singular quotients in geometric invariant theory. *Transformation Groups* **8** (2003), 217-259.
26. (with V. Guillemin and R. Sjamaar) Symplectic implosion. *Transformation Groups* **7** (2002) 155-184.
27. The Verlinde formula for parabolic bundles, *J. London Math. Soc.* **63** (2001) 754-768.
28. (with J. Hurtubise) Representations with weighted frames and framed parabolic bundles. *Canad. J. Math.* **52** (2000) 1235-1268.
29. (with J. Weitsman) Symplectic geometry of the moduli space of flat connections on a Riemann surface: inductive decompositions and vanishing theorems. *Canad. J. Math.* **52** (2000) 582-612.
30. (with F.C. Kirwan) Intersection pairings in moduli spaces of holomorphic bundles of arbitrary rank on a Riemann surface. *Annals of Mathematics* **148**, 109-196 (1998).
31. (with K. Guruprasad, J. Huebschmann and A. Weinstein) Group systems, groupoids, and moduli spaces of parabolic bundles. *Duke Math. J.* **89**, 377-412 (1997).
32. (with F.C. Kirwan) Localization and the quantization conjecture. *Topology* **36**, 647-693 (1997).
33. (with J. Weitsman) A perfect Morse function on the moduli space of flat connections on a Riemann surface. *Compositio Math.*, **105**, 147-151 (1997).
34. (with J. Weitsman) Toric structures on the moduli space of flat connections on a Riemann surface II: inductive decomposition of the moduli space. *Math. Annalen* **307**, 93-108 (1997).
35. Review of *Introduction to Symplectic Topology* (D. McDuff, D. Salamon), *Bull. Amer. Math. Soc.* **34**, 441-446 (1997).
36. Quantum field theory, equivariant cohomology, symplectic geometry and moduli spaces of vector bundles on Riemann surfaces. *Geometry and physics* (Aarhus, 1995), 33–57, *Lecture Notes in Pure and Appl. Math.*, **184**, Dekker, New York, 1997. (Refereed lecture notes.)
37. (with F.C. Kirwan) On localization and Riemann-Roch numbers for symplectic quo-

- tients. *Quart. J. Math.* **47**, 165-186 (1996).
38. (with F.C. Kirwan) Intersection pairings in moduli spaces of holomorphic bundles on a Riemann surface. *Electronic Res. Notices of the AMS* **1**, 57-71 (1995).
  39. Group cohomology construction of the cohomology of moduli spaces of flat connections on 2-manifolds. *Duke Math. J.* **77**, 407-429 (1995).
  40. (with J. Weitsman) Torus actions and the topology and symplectic geometry of flat connections on 2-manifolds. In the Proceedings of the Taniguchi Foundation Symposium on Low Dimensional Topology and Topological Field Theory (Kyoto, January 1993), ed. K. Fukaya, M. Furuta, T. Kohno and D. Kotschick, World Scientific, 49-58 (1994). (Refereed conference proceedings.)
  41. Symplectic forms on moduli spaces of flat connections on 2-manifolds. Proceedings of the Georgia International Topology Conference (Athens, GA, 1993), ed. W. Kazez, Amer. Math. Soc./International Press AMS/IP Studies in Advanced Mathematics **2**, 268-281 (1997). (Refereed conference proceedings.)
  42. (with F.C. Kirwan) Localization for nonabelian group actions. *Topology* **34**, 291-327 (1995).
  43. Extended moduli spaces of flat connections on Riemann surfaces. *Math. Annalen* **298**, 667-692 (1994).
  44. (with J. Weitsman) Toric structures on the moduli space of flat connections on a Riemann surface: volumes and the moment map. *Advances in Mathematics* **109**, 151-168 (1994).
  45. (with J. Huebschmann) Group cohomology construction of symplectic forms on certain moduli spaces. *International Mathematics Research Notices* **6**, 245-249 (1994).
  46. (with J. Weitsman) Half density quantization of the moduli space of flat connections and Witten's semiclassical manifold invariants. *Topology* **32**, 509-529 (1993).
  47. (with J. Weitsman) Bohr-Sommerfeld orbits in the moduli space of flat connections and the Verlinde dimension formula. *Commun. Math. Phys.* **150**, 593-630 (1992).
  48. Chern-Simons-Witten invariants of lens spaces and torus bundles, and the semiclassical approximation. *Commun. Math. Phys.* **147**, 563-604 (1992).
  49. (with M.F. Atiyah) Topological Lagrangians and cohomology. *J. Geom. Phys.* **7**, 119-136 (1990).
  50. Feasibility of a low-mass binary source progenitor for PSR 1937+214. *Nature* **319**, 384 (1986).

7c. books edited

1. (with P. Deligne, P. Etingof, D. Freed, D. Kazhdan, J. Morgan, D. Morrison, E. Witten, eds.) *Quantum Fields and Strings: A Course for Mathematicians*. Proceedings of Program on Quantum Field Theory (IAS, Princeton, NJ, 1996-7), American Mathematical Society, Providence, RI (1999).

## 8. Non-refereed Publications

1. (with Augustin-Liviu Mare) On the image of real loci of symplectic manifolds under moment maps. Oberwolfach research report no. 09/2011, 3pp., to appear.

2. Invited (by Claudio Bartocci) to contribute an article on “Invariants (from Euler to Hilbert, from Alexander to Witten)” to a volume “Mathematics and Culture” published by Einaudi (Michael Atiyah is the chairman of the scientific advisory board). I had to decline this invitation because the deadline for the article was too soon.
3. Book Review: *Integrable Systems: From Classical to Quantum* by J. Harnad and J. Hurtubise, Canadian Mathematical Society Notes, Vol. 34 no. 3 (April 2002), p. 5-6.
4. Hamiltonian group actions and symplectic reduction. In *Symplectic Geometry and Topology*, ed. Y. Eliashberg and L. Traynor, American Mathematical Soc., 1999, p. 295-333.
5. Quantum gauge theories in two dimensions and intersection theory on moduli spaces (notes of a lecture by E. Witten), in Proceedings of Program on Quantum Field Theory (IAS), Amer. Mathematical Society, 1999.
6. (with S. Wu) Solution to Problem 1 of December problem set (in Proceedings of Program on Quantum Field Theory, IAS).
7. Quantum Field Theory (notes of five lectures by L. Faddeev), (in Proceedings of Program on Quantum Field Theory, IAS), Amer. Mathematical Society:
  - Lecture 1: Reminder of basics of quantum mechanics and canonical quantization in Hilbert space.
  - Lecture 2: The harmonic oscillator and free fields.
  - Lecture 3: Comments on scattering.
  - Lecture 4: Singular Lagrangians
  - Lecture 5: Quantization of Yang-Mills fields.
8. (with F.C. Kirwan) A note on localization and the Riemann-Roch formula. In “Functional analysis on the eve of the twenty-first century”, ed. S. Gindikin (Proceedings of a conference in honour of the eightieth birthday of I.M. Gelfand, Rutgers Univ., October 1993), Birkhäuser, Progress in Mathematics **132**, 283-299 (1995).
9. (with J. Weitsman) Torus actions, moment maps, and the symplectic geometry of the moduli space of flat connections on a two-manifold. In Proceedings of NATO Advanced Research Workshop on Low Dimensional Topology and Quantum Field Theory (Isaac Newton Institute, Cambridge, September 1992), ed. H. Osborn (NATO ASI Series B: Physics, vol. 315), Plenum Press, 307-316 (1993); and in the proceedings of the AMS Summer Conference on Conformal Field Theory, Topological Field Theory and Quantum Groups (Mt. Holyoke, June 1992) (ed. P. Sally), Contemporary Mathematics **175**, 149-159 (1995).
10. (with J. Weitsman) Geometric quantization and the stationary phase approximation to the Witten-Reshetikhin-Turaev invariants. In Proceedings of the NATO Advanced Research Workshop on Low Dimensional Topology and Quantum Field Theory (Isaac Newton Institute, Cambridge, September 1992), ed. H. Osborn (NATO ASI Series B: Physics, vol. 135), Plenum Press, 317-322 (1993).
11. New results in Chern-Simons gauge theory (notes of lectures by E. Witten). In Proc. of the LMS Symposium on the Geometry of Low Dimensional Manifolds (Durham, 1989), ed. S.K. Donaldson and C.B. Thomas (LMS Mathematics Lecture Series vol.

150), 73-95 (1991).

**9. Manuscripts/publications, etc. in preparation and submitted to publishers but not yet accepted**

**10. Papers presented at meetings and symposia**

1. Invited to give a lecture at Special Session on Symplectic Geometry, AMS Regional Meeting, Georgia Southern University, March 2011 (my former PhD student Tom Baird spoke instead at this meeting)
2. “Real loci of based loop groups”, Texas Geometry and Topology Conference, TAMU, College Station, TX, November 2010
3. “Representations of surface groups and real loci”, conference ”Surfaces and Representations”, Sherbrooke, QC, October 2010
4. Invited to give a 50-minute lecture at Canada-Korea Special Session on Algebraic Geometry, CMS 2009 Summer Meeting, St. John’s, Newfoundland (unable to attend meeting)
5. ”Connectedness of level sets of the moment map for torus actions on the based loop group”: A Celebration of Raoul Bott’s Legacy in Mathematics, CRM, June 2008.
6. Invited to give a lecture in Special Session on “Poisson geometry and mathematical physics” at Canadian Mathematical Society winter meeting, Toronto, December 2006 (I gave my speaker slot to my graduate student Tom Baird).
7. Invited to participate in Geometry conference in honour of Nigel Hitchin in honour of his 60th birthday (Madrid, 4-8 September 2006) (accepted)
8. ‘Intersection pairings in singular moduli spaces of bundles’, Clay Mathematics Institute Workshop on Moduli Spaces of Vector Bundles, Cambridge, MA, October 2006
9. Invited to visit New Mexico State University and give a lecture and colloquium (declined)
10. Participated in Great Lakes Geometry Conference, Perimeter Institute, April 30 – May 1, 2005
11. Participated in *Strings ’05* (University of Toronto, July 2005).
12. (with Nan-Kuo Ho) Representations of fundamental groups of nonorientable 2-manifolds. Algebraic structures and moduli spaces, 139–147, CRM Proc. Lecture Notes, 38, Amer. Math. Soc., Providence, RI, 2004.
13. (with F.C. Kirwan) Applications of equivariant cohomology to symplectic geometry and moduli spaces, in *Geometric Analysis and Lie Theory in Mathematics and Physics* (A. Carey and M. Murray, ed.), Australian Mathematical Society Lecture Series **11**, Cambridge Univ. Press (1998) 1-19. (Refereed lecture notes)
14. Quantum field theory, equivariant cohomology, symplectic geometry and moduli spaces of vector bundles on Riemann surfaces. In *Proceedings on Geometry and Physics* (Aarhus/Odense, Denmark, July 1995), eds. J. Andersen, J. Dupont, H. Pedersen and A. Swann, Marcel Dekker (Lecture Notes in Pure and Applied Mathematics), 33-58 (1997). (Refereed lecture notes)

**11. Invited lectures**

(i) Research lectures:

1. “Toric varieties related to moduli spaces of flat connections on 2-manifolds”, Topology seminar, SUNY Buffalo, April 2010
2. “Real loci and the based loop group”, Symplectic Geometry seminar, University of Toronto, October 2009
3. “Convexity and loop groups”: Ontario Topology Seminar, July 2007.
4. “Intersection numbers on singular moduli spaces of bundles”:
  - Clay Mathematics Institute Workshop on Moduli Spaces of Vector Bundles, Cambridge, MA, October 2006
  - Symplectic Geometry seminar, University of Toronto, December 2005.
5. “Intersection numbers in reduced spaces of quasi-Hamiltonian spaces”:
  - “Geometry and Algebraic Groups”, Conference in Honour of Robert MacPherson, IAS, Princeton, NJ, October 2004
  - Cohomological Aspects of Hamiltonian Group Actions and Toric Varieties, Oberwolfach (Germany), April 2004
6. “Localization, the residue formula and the kernel of the Kirwan map”, AIM (Workshop on Moment Maps in Various Geometries), Palo Alto, CA, August 2004
7. “Representations of fundamental groups of nonorientable 2-manifolds”: Conference on Algebraic Structures and Moduli Spaces, CRM, Montréal, July 2003
  - VBAC (Conference on Moduli Spaces), Porto, Portugal, July 2003
  - Conference on Symplectic Geometry, ESI, Vienna, August 2003
8. “The kernel of the Kirwan map”, Harvard University, May 2003
9. “The residue formula and some of its applications”, Harvard University, May 2003
10. “Moduli spaces and symplectic geometry”, Harvard University, May 2003
11. “The residue formula and the Tolman-Weitsman theorem”, AMS Special Session on Integrable Systems (Courant Institute), April 2003. (Lecture not delivered because of reluctance to travel to New York City at that time.)
12. “The residue formula and the Tolman-Weitsman theorem”: Symplectic Geometry Seminar, University of Toronto, February 2003.
13. “The residue formula and the Tolman-Weitsman theorem”: Topology Seminar, Montréal, January 2003.
14. “The residue formula and the Tolman-Weitsman theorem”: Conference, Strasbourg, May 2002.
15. “Intersection pairings on singular quotients”:
  - Conference on Symplectic and Contact Geometry and Group Actions, MIT, April 2002.
  - Symposium, Fields Institute (Toronto), March 2002
  - Workshop on the Geometry of Infinite-dimensional Lie Groups, CRM (Montréal), October 2001
  - CMS Special Session, McMaster Univ., June 2000
16. “Imploded cross-sections and moduli spaces of flat connections on Riemann surfaces”, AMS Special Session, Univ. of Toronto, September 2000

17. “Moduli spaces of flat connections on 2-manifolds”, AMS Special Session, SUNY at Buffalo, April 1999.
18. “The Verlinde formula for parabolic bundles”, Conference on Symplectic Geometry, IST (Lisbon, Portugal), June 1999.
19. “The Verlinde formula for moduli spaces of parabolic bundles”:
  - Workshop on Moduli Spaces, Stanford University, August 2001
  - Workshop on Quantization, CRM, Montréal, September 1999
  - Geometry seminar, McMaster University, April 1999
  - Canadian Math. Soc. Conference, Kingston, ON, December 1998
  - AMS Special Session, Penn State Univ., October 1998.
20. “Holomorphic bundles and the Verlinde formula”:
  - Geometry Seminar (Northwestern University), December 1997
  - Algebraic Geometry Seminar (Cornell University), November 1997
  - AMS Special Session (Montréal), September 1997
21. Lectures on the cohomology of moduli spaces of vector bundles on Riemann surfaces (4 lectures), Université Paris-Sud, September-October 1997:
  - 1. “Introduction à l’espace de modules de fibrés vectoriels sur les surfaces de Riemann”.
  - 2. “Les formules de Witten pour les nombres d’intersection dans les espaces de modules de fibrés vectoriels sur les surfaces de Riemann”
  - 3. “Les conséquences des formules pour les nombres d’intersection: La formule de Verlinde”
  - 4. “Théorèmes d’annulation dans la cohomologie des espaces de modules”
22. “La cohomologie de l’espace de modules de fibrés vectoriels sur une surface de Riemann”:
  - Université de Strasbourg (Séminaire de Topologie), September 1997.
  - Ecole Normale Supérieure (Séminaire), September 1997.
23. “Intersection pairings in the cohomology of moduli spaces on Riemann surfaces and the Verlinde formula”, Conference in honour of the 50th birthday of A. Beauville (CIRM, Luminy, France), May 1997.
24. “Witten’s generalized Bernoulli polynomials and the cohomology of moduli spaces”, Rutgers University (Lie groups seminar), February 1997.
25. “Cohomology of moduli spaces of vector bundles on Riemann surfaces”: Courant Institute (Geometry and Topology Seminar), December 1996.
26. “Vanishing theorems in the cohomology of moduli spaces of flat connections on Riemann surfaces”:
  - Fields Institute, Toronto (Workshop on Symplectic Geometry), June 1997.
  - MIT (Conference on Symplectic Geometry), April 1997
  - Univ. of North Carolina (Seminar), April 1997
  - Workshop on Geometry and Physics, Univ. of Florida, Gainesville, FL, February 1997
  - Princeton University (Topology Seminar), November 1996.

27. “Flat connections on Riemann surfaces”:
  - Symposium for new members of Royal Society, Fields Institute, March 2008.
  - Invited lecture, University of Toronto, March 1997
  - Columbia, MO (AMS Meeting, Special Session on Lie Groups and Physics), November 1996.
28. “Vanishing theorems in the Pontrjagin ring of moduli spaces”: Columbia, MO (AMS Meeting, Special Session on Gauge Theory and its Interaction with Holomorphic and Symplectic Geometry), November 1996.
29. “Torus actions and symplectic volumes of moduli spaces”: Lawrenceville, NJ (AMS Meeting, Special Session on Moduli Spaces of Vector Bundles Over Curves With or Without Additional Structure), October 1996.
30. “Intersection theory in moduli spaces of holomorphic bundles on a Riemann surface”: Oberwolfach (Germany) (Conference on Moduli Spaces), September 1996.
31. “Intersection pairings on moduli spaces of holomorphic bundles on a Riemann surface”:
  - CIRM, Luminy (France) (Conference on Symplectic Geometry, Multiplicities and Quantization), July 1996.
  - Oberwolfach (Germany) (Conference on Geometry and Analysis of Singular Spaces), June 1996.
32. “Flat connections on Riemann surfaces”: Univ. of Illinois (Urbana) (Topology seminar), April 1996.
33. “Quantization commutes with reduction”: Fields Institute (Toronto), “Homotopy, Geometry and Physics” meeting, April 1996.
34. “Intersection pairings on the moduli space of flat connections on a Riemann surface”: McMaster University (Topology seminar), March 1996.
35. “Quantization commutes with reduction”: Penn State University (Geometry and gravity seminar), February 1996.
36. “Intersection pairings in the moduli space of flat connections on a Riemann surface”: Penn State University (Workshop on Symplectic Geometry), February 1996.
37. “Intersection pairings in the moduli space of flat connections on a Riemann surface”: AMS Meeting, Orlando, FL (Special Session on Noncompact Manifolds), January 1996.
38. “Intersection pairings in the moduli space of vector bundles on a Riemann surface”: AMS Meeting, Northeastern University (Special Session on Geometry and Quantum Field Theory), October 1995.
39. “Intersection pairings on moduli spaces of vector bundles on a Riemann surface”: University of Massachusetts, Amherst (Valley Geometry Seminar), October 1995.
40. “Witten’s formulas for intersection pairings in the moduli space of bundles on a Riemann surface”: Institut Henri Poincaré, Paris (Conference on Vector Bundles on Curves), June 1995.
41. “Intersection pairings on moduli spaces on a Riemann surface and two dimensional Yang-Mills theory”: Université de Strasbourg (Colloque “Rencontres”), June 1995.
42. “Intersection theory for moduli spaces of vector bundles on curves”: Institut Henri Poincaré, Paris (Seminar), May 1995.

43. “La quantification commute à la reduction”: Ecole Normale Supérieure, Paris (two seminars), May 1995.
44. “Localization and Riemann-Roch numbers for symplectic quotients”: American Mathematical Society, Special Session (Hartford, CT), March 1995.
45. “Intersection numbers in moduli spaces of holomorphic bundles on a Riemann surface”:
  - University of Chicago (Meeting in honour of N. Hitchin), April 1995.
  - International Centre for Theoretical Physics (Trieste, Italy), Conference on Geometry and Physics, March 1995.
46. “De Rham representatives for the cohomology of flat connections on 2-manifolds”: Conference on Singular Spaces (Oberwolfach, Germany), July 1994.
47. “Group Cohomology Construction of the Cohomology of Moduli Spaces of Flat Connections on 2-manifolds”: AMS Meeting (Polytechnic University of New York), Special Session on Gauge Theory, April 1994.
48. “Equivariant Cohomology and Pairings in the Cohomology of Symplectic Quotients”: Conference in honour of the eightieth birthday of I.M. Gelfand, (Rutgers University), October 1993.
49. “Localization for Nonabelian Group Actions”:
  - Georgia International Topology Conference (Athens, GA), August 1993.
  - LMS Symposium on Vector Bundles in Algebraic Geometry (Durham, UK), July 1993.
50. “Torus Actions and the Topology of Moduli Spaces”: Taniguchi Foundation Symposium (Low Dimensional Topology and Topological Field Theory), Kyoto (Japan), January 1993.
51. “Symplectic Geometry and Extended Moduli Spaces”: Kyoto Conference (3-4 dimensional Topology and Field Theory), Kyoto (Japan), January 1993.
52. “Symplectic Geometry and Flat Connections on Riemann Surfaces”, Conference on 4-manifolds (Oberwolfach, Germany), September 1992.
53. “Witten-Reshetikhin-Turaev Invariants and the Semiclassical Approximation”: AMS Meeting (Lehigh University), Special Session on New Invariants of Links and 3-Manifolds, April 1992.

*(ii): Colloquium lectures and other general lectures*

1. “Stationary phase approximation”, PSCD02 lecture, UTSC, April 2006.
2. “Flat connections on Riemann surfaces”, Algebraic Geometry seminar, University of Toronto, October 2005.
3. “Gauge theories and flat connections on Riemann surfaces”, Colloquium, University of Waterloo, November 2004.
4. “Hamiltonian flows and the stationary phase approximation”:
  - WIM talk, University of Waterloo, November 2004.
  - Graduate seminar, University of Toronto, March 2005
5. “Program on the Geometry of String Theory”, Fields Institute Annual General Meeting, June 2005
6. “Cohomology rings of symplectic quotients”: Colloquium, Montréal, January 2003.

7. “Symplectic quotients and their cohomology”: Coxeter-James Lecture, Canadian Mathematical Society Winter Meeting, University of Ottawa, December 2002.
8. “Symplectic Topology, Geometry and Gauge Theory”: Fields Institute lecture (concluding lecture for thematic program on symplectic geometry), June 2001
9. “Gauge theories and flat connections on Riemann surfaces”: Krieger-Nelson Lecture, Canadian Mathematical Society Summer Meeting, University of Saskatchewan, June 2001
10. “Quantum gauge theories in two dimensions”: Colloquium, Department of Physics, University of Toronto, November 2000
11. “Hamiltonian group actions” (three lectures): Distinguished Lecture Series, University of Western Ontario, March 1999
12. “On the Verlinde formula”: Colloquium, University of New Brunswick, December 1997
13. “Flat connections on Riemann surfaces”: Colloquium, Northwestern University, December 1997
14. “Flat connections on Riemann surfaces”: Plenary lecture, AMS Meeting, College Park, MD, April 1997.
15. “Flat connections on Riemann surfaces”: Colloquium, Univ. of North Carolina, April 1997
16. “Flat connections on Riemann surfaces”: Aisenstadt Prize lecture (CRM, Université de Montréal), February 1997.
17. “Flat connections on Riemann surfaces”: Colloquium, University of New Brunswick, December 1996.
18. “Flat connections on Riemann surfaces” (two lectures): Fields Institute, Toronto (Poincaré lecture series), May 1996.  
(Each invited speaker in this weekly lecture series gives one lecture for a general mathematical audience followed by a more specialized lecture.)
19. “Flat connections on Riemann surfaces”: Purdue University (Colloquium), April 1996.
20. “Flat connections on Riemann surfaces and two dimensional Yang-Mills theory”: Cornell University (Colloquium), March 1996.
21. “Flat connections on Riemann surfaces”: Rice University (Colloquium), November 1995.
22. “Nombres d’intersection dans la variété de modules des fibrés semistables sur une surface de Riemann”: Université de Paris VII (Colloque ‘Journées Solstice’), June 1995.  
(This lecture was given as part of a two-day conference with the title “Algèbres et Groupes”, and was intended to be accessible to a broad mathematical audience.)
23. “Intersection numbers in moduli spaces of holomorphic bundles on a Riemann surface”: Princeton University (Colloquium), February 1995.
24. “Localization Principles in Symplectic Geometry and Equivariant Cohomology”:
  - MIT (Colloquium), May 1994.
  - University of Toronto (Colloquium), January 1994.
25. “Geometric Quantization and the Stationary Phase Approximation to the Witten-

- Reshetikhin-Turaev Invariants”: McMaster University (Colloquium), January 1993.
26. “Volumes of Moduli Spaces of Flat Connections on Riemann Surfaces”: New York University (Geometry Festival), April 1992.  
(The Geometry Festival is a three-day meeting held annually, and organized jointly by several universities in the northeastern United States. Less than ten speakers are invited to give plenary one-hour lectures which are intended to be accessible to a fairly general audience.)
27. “Geometric Quantization and Flat Connections on Riemann Surfaces”:  
 •Columbia University (Colloquium), October 1991  
 •Brown University (Colloquium), October 1991.

## D. List of Courses

### 12. Courses taught

#### 12a. undergrad courses taught

1. Univ. of Toronto at Scarborough, Jan.-May 2011, Jan.-May 2010, Jan.-May 2007, MAT C46S (Differential Equations II)<sup>1</sup>  
 Textbook: W. Boyce, R. Di Prima, Elementary differential equations and boundary value problems (8th edition) chapters 6 and 9 – 11  
 Syllabus:
- (a) Laplace Transforms (text, Chap. 6)
  - (b) Phase portraits (text, Chap. 9); Equilibrium points, Liapunov’s Second Method (text, Chap. 9.6)
  - (c) Periodic solutions (text, Chap. 9.7)
  - (d) Boundary value problems (text, Chap. 10)
  - (e) Partial differential equations (text, Chap. 10)
  - (f) Sturm-Liouville problems (text, Chap. 11)

Marking scheme:

- (a) Assignments 30%
- (b) Midterm exam 25%
- (c) Final exam 45%

Assignments will be given every other week. Although you are expected to do all the questions, the grader will assign grades based on a selection of your solutions.

2. Univ. of Toronto at Scarborough, Sept.-Dec. 2000, Sept.-Dec. 2001 and Sept.-Dec. 2002, MAT C34F (Complex Variables)<sup>2</sup>  
*Course outline:*

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<sup>1</sup>I had major responsibility for the design of the course.

<sup>2</sup>I had major responsibility for the design of this course, although I adhered closely to the existing syllabus.

**Textbooks:** *Required text:* H. Priestley, *Introduction to Complex Analysis* (2nd edition).

*Supplementary text:* Murray R. Spiegel, *Complex Variables* (Schaum's Outlines Series).

**Syllabus:** (All numbers refer to the text by Priestley)

A1: The complex plane (Chap. 1);

holomorphic functions and power series (Chap. 2)

A2: Cauchy's theorem (Chaps. 3 and 4)

A3: Cauchy's integral formula, zeros of holomorphic functions, maximum modulus theorem, open mapping theorem, Liouville's theorem (Chap. 5)

A4: Laurent's theorem, meromorphic functions, singularities, branch points, branch cuts, poles, residues (Chap. 6)

A5: Cauchy's residue theorem (Chap. 7);  
applications of contour integration, Schwarz's lemma,  
argument principle (Chap. 8)

A6: Conformal mapping and harmonic functions (Chap. 10)

**Marking scheme:** Assignments 20 %, 2 midterms 15 % each, final 50 %

3. Univ. of Toronto at Scarborough, Sept.-Dec. 1998, Sept.-Dec. 1999 and Sept.-Dec. 2003, Sept.-Dec. 2006, Sept.-Dec. 2009, MAT B44 (Ordinary Differential Equations)<sup>3</sup>

4. McGill University, Sept.-Dec. 1995, 189-315A (Ordinary Differential Equations)

*Course outline:*

First order ordinary differential equations including elementary numerical methods.

Linear differential equations.

Series solutions.

Text: Elementary Differential Equations and Boundary Value Problems (Boyce and di Prima, 8th edition), chapters 2-5, 7.

5. Princeton University, Sept.-Jan. 1993, Jan.-April 1994, Math 104 (second course in calculus sequence: one variable calculus)

6. Cambridge University, Jan. - Mar. 1993, tutorials for Differential Analysis and Geometry (final year undergraduate course).

7. Oxford University, Oct.-Dec. 1989, problems class for Complex Algebraic Curves (final year undergraduate course).

## 12b. graduate courses taught<sup>4</sup>

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<sup>3</sup>I did not have major responsibility for the design of this course.

<sup>4</sup>In courses 3 and 4 I had major responsibility for the design of the course. In courses 1 and 2 the design of the course was dictated by the qualifying exam syllabus.

1. Univ. of Toronto, Sept —Dec 2010, MAT1300F (Differentiable Manifolds)

*Course outline:*

- (a) Smooth manifolds; smooth maps between manifolds; submanifolds; immersions, embeddings, the inverse and implicit function theorems; the rank theorem
- (b) Smooth manifolds
- (c) Tangent spaces; submanifolds and smooth maps between manifolds
- (d) The tangent and cotangent bundle; vector bundles
- (e) Differential forms, exterior derivative
- (f) Vector fields; flows on manifolds; Lie derivative
- (g) Integration on manifolds; Stokes' theorem
- (h) Poincaré lemma, de Rham cohomology, Mayer-Vietoris sequence in de Rham cohomology
- (i) Lie groups  
If time permits, an introductory treatment of a selection of the following additional topics will be given:
- (j) Riemannian metrics
- (k) Connections and curvature

Suggested reading: L. Springer V. Guillemin, A. Pollack, Differential topology (Prentice-Hall, 1974)

2. Univ. of Toronto, Jan —April 2010, MAT1301S (Topology)

*Course outline:*

- (a) Homotopy
- (b) Covering spaces
- (c) Van Kampen's theorem
- (d) Homological algebra
- (e) Singular homology
- (f) Applications of homology
- (g) Cellular homology
- (h) Jordan curve theorem
- (i) Cohomology
- (j) Cup products
- (k) Homology with coefficients
- (l) Orientation
- (m) Poincaré duality
- (n) Classification of surfaces
- (o) Universal coefficient theorem
- (p) Hodge star operator

(q) Hurewicz homomorphism

Text: Hatcher, *Algebraic Topology*

3. Univ. of Toronto, Jan— April 2007, MAT1300Y (Topology) (joint with P. Selick)

Course outline:

(a) Set theory

(b) Topological spaces, groups and manifolds

(c) Compactness

(d) Separation axioms

(e) Metric spaces

(f) Paracompactness

(g) Connectedness; Local Properties

(h) CW-complexes

(i) Category theory

(j) Homotopy

(k) Covering spaces

(l) Van Kampen's theorem

(m) Homological algebra

(n) Singular homology

(o) Applications of homology

(p) Cellular homology

(q) Jordan curve theorem

(r) Cohomology

(s) Cup products

(t) Homology with coefficients

(u) Orientation

(v) Poincaré duality

(w) Classification of surfaces

(x) H-spaces

(y) Hurewicz homomorphism

I taught the first term, which comprised almost all the material up to and including Van Kampen's theorem. I also taught the sections on applications of homology and classification of surfaces in the second term. Marking scheme:

4. Univ. of Toronto, Jan-April 2001, MAT1312S (Symplectic Geometry and Hamiltonian group actions)

*Course outline:*

- (a) Moment maps; symplectic quotients
- (b) The symplectic structure on coadjoint orbits
- (c) Proof of the Atiyah-Bott-Guillemin-Sternberg convexity theorem via Morse theory
- (d) The Duistermaat-Heckman theorem, version 1 (on the volume of symplectic quotients)
- (e) The Duistermaat-Heckman theorem, version 2 (on an exact formula for the value of an oscillatory integral over a symplectic manifold; this may be summarized by the statement that the stationary phase approximation for this formula is exact)
- (f) Equivariant cohomology
- (g) the localization theorem of Atiyah-Bott-Berline-Vergne
- (h) Cohomology rings of symplectic quotients
- (i) Geometric quantization

*Suggested reading:*

- 1. M. Audin, *The Topology of Torus Actions on Symplectic Manifolds*, Birkhauser, Progress in Mathematics vol. 93 (1991).
- 2. V. Guillemin, *Moment maps and combinatorial invariants of Hamiltonian  $T^n$ -spaces*, Birkhäuser (1994).
- 3. V. Guillemin, S. Sternberg, *Supersymmetry and equivariant de Rham theory*, Springer-Verlag (1999).

5. Univ. of Toronto, Jan-April 2004, MAT1343S (Differentiable Manifolds)  
6. Univ. of Toronto, Jan-April 2000, MAT1341S (Manifolds and Differential Geometry)  
7. Univ. of Toronto, Jan-April 1999, MAT1343S (Manifolds and Differential Geometry)  
8. McGill University, Jan-April 1998, 189-577B (Geometry and Topology II)

*Course outline (MAT1341S: the other two courses had similar course outlines):*

- (a) Smooth manifolds; smooth maps between manifolds; submanifolds; immersions, embeddings, the inverse and implicit function theorems; the rank theorem
- (b) Smooth manifolds
- (c) Tangent spaces; submanifolds and smooth maps between manifolds
- (d) The tangent and cotangent bundle; vector bundles
- (e) Differential forms, exterior derivative
- (f) Vector fields; flows on manifolds; Lie derivative
- (g) Integration on manifolds; Stokes' theorem
- (h) Poincaré lemma, de Rham cohomology, Mayer-Vietoris sequence in de Rham cohomology

(i) Lie groups

If time permits, an introductory treatment of a selection of the following additional topics will be given:

(j) Riemannian metrics

(k) Connections and curvature

Suggested reading: L. Conlon, *Differentiable manifolds: a first course* (Birkhäuser, 1993); V. Guillemin, A. Pollack, *Differential topology* (Prentice-Hall, 1974)

9. McGill University, Jan- April 1996, 189-709B (Topics in Geometry and Topology)

This was a graduate course on symplectic geometry; since the course presented recent or current research, I prepared the lectures starting from research articles, some of which were distributed to the students.

*Course outline:*

Symplectic geometry arises from physics: a symplectic manifold (a manifold equipped with a nondegenerate closed two-form) is the natural mathematical generalization of the phase space considered in classical mechanics. Techniques from symplectic geometry have strong interrelations with quantum field theory. Because coadjoint orbits are symplectic manifolds, there are also applications to the representation theory of compact groups.

The course will cover the following material:

(1) Introduction: Symplectic manifolds, the Darboux-Weinstein theorem, vector bundles, connections, Lie groups.

(2) Hamiltonian group actions:

a. Moment maps; symplectic quotients

b. The Atiyah-Bott-Guillemin-Sternberg convexity theorem

c. Delzant's theorem and introduction to toric geometry

(3) The symplectic structure on coadjoint orbits

(4) Geometric quantization; applications to representation theory (survey)

(5) a. Equivariant cohomology and applications to symplectic geometry: the localization theorem of Berline-Vergne, the Duistermaat-Heckman theorem

b. recent results on cohomology rings of symplectic quotients, obtained using localization: a survey

(6) An infinite dimensional symplectic quotient: the moduli space of flat connections on a Riemann surface (following Atiyah-Bott 1982 and Goldman 1984).

Suggested references:

1. M. Audin, *The Topology of Torus Actions on Symplectic Manifolds*, Birkhauser, Progress in Mathematics vol. 93 (1991).

2. N. Berline, E. Getzler, M. Vergne, *Heat Kernels and Dirac Operators*, Springer-Verlag (Grundlehren v. 298) (1992), chap. 7.

3. V. Guillemin, S. Sternberg, *Symplectic Techniques in Physics*, Cambridge University Press (1984).

## 12c. theses supervised

(i) *Final year honours projects:*

University of Toronto; Alex Markos, supervised four half reading courses during 1998-9 and 1999-2000

Sam Kaufman, supervised one half reading course during 2002-3

Nikita Nikolaev, supervised one half reading course (Complex Projective Space) during 2010

Katya Tello, supervised one half reading course (MATD95, Real Analysis) during 2010.

McGill University; 189-470B/D ; Honours project (directed reading and preparation of a written report). The student is assigned a project supervisor and a project topic at the beginning of the semester; the project consists of a written report including a literature survey and is tested by an oral examination.

1. E. Robidoux (half year). Title: Riemann surfaces

2. P. Hayden (full year). Title: Witten's formulas for symplectic volumes of moduli spaces

(ii) *Summer undergraduate students:*

Yan (Mary) He, 2010 (UTEA, joint with P. Selick)

Yan (Mary) He, 2009 (UTEA, joint with P. Selick)

Mo Lu Shi, Xiacong Han, 2007 (UTEA)

Xiaoping Peng, 2007 (NSERC USRA)

Ivona Simic, 2006 (NSERC USRA)

Anja Kortenaar, 2005 (NSERC USRA)

Travis Li, 2005 (NSERC USRA)

Francis Chung, 2004 (NSERC USRA)

Heather Gray, 2002 (NSERC USRA), supervised jointly with P. Selick

Sunny Arkani-Hamed, 2001 (NSERC USRA)

David Serpa, 1999 (NSERC USRA), 2000

(i) *Masters students:* Peter Crooks, 2010, supervised M.Sc. reading project (title "Symplectic geometry")

Kathleen Smith, 2005, supervised M.Sc. reading project (title "Symplectic Geometry")

Sean Fitzpatrick, 2004, supervised M.Sc. reading project (title "Symplectic Geometry")

Brendan McLellan, 2004, supervised M.Sc. reading project (title "Symplectic Geometry")

Tom Baird, 2002, supervised M.Sc. reading project (title "Symplectic Geometry")

Alex Markos, 2001, supervised M.Sc. reading project (title "Symplectic topology, geometry and mathematical physics")

(ii) *Doctoral students:*

(iii) *Doctoral students who have completed their Ph.D.:*

David Klein, 2002–2008 (Ph.D. completed August 2008; has accepted a tenure track position at Brandon University)

Title: The Goldman flow on the moduli space of flat connections on a nonorientable 2-manifold

Tom Baird, 2002– 2007 (Ph.D. completed November 2007, jointly supervised with Paul Selick; winner of the Canada Scholarship and NSERC PDF, now holds a tenure track position at Memorial University)

Title: The moduli space of flat  $SU(2)$  connections over a nonorientable surface

Mark Hamilton, 2000 – 2005 (Ph.D. completed July 2005, jointly supervised with Yael Karshon after summer 2004)

Title: Singular Bohr-Sommerfeld leaves and geometric quantization

Present status: Assistant Professor, Mount Allison University

Joon-Hyeok Song, 2000 –2004 (Ph.D. completed June 2004)

Title: Intersection numbers in reduced spaces of quasi-Hamiltonian spaces

Present status: Teacher at private school

Nan-Kuo Ho, 2000 –2003 (Ph.D. completed July 2003, awarded NSERC Postdoctoral Fellowship, 2004. Present status: Associate Professor, National Tsinghua University, Taiwan)

Title: The moduli space of gauge equivalence classes of flat connections over a compact nonorientable surface

Ramin Mohammadikhani, 1998 –2002 (Ph.D. completed July 2002, held NSERC postdoctoral fellow at CRM, Montréal 2003–6; now student of computer science at Concordia University)

Title: Cohomology ring of symplectic reductions by circle actions

Allen Knutson, 1993-4, co-supervisor (second year Ph.D. student at Princeton University).

Knutson had passed his qualifying examination in October 1993 and was beginning research. With my guidance he developed a keen interest and expertise in symplectic geometry. I encouraged him to transfer to MIT and work under the supervision of Victor Guillemin, where he would be able to interact with a large group of students and postdoctoral fellows in this area. He has now completed his Ph.D. dissertation, and I was the external examiner at his thesis defence (May 1996).

Present status: Professor, Cornell University

(*iib*) *Doctoral students whose Ph.D. is in progress:*

Peter Crooks, January 2011 – (Ph.D. in progress)

Jonathan Fisher, May 2009 – (Ph.D. in progress)

Songhao Travis Li, September 2008– (Ph.D. in progress, joint with Marco Gualtieri)

Title: Poisson manifolds

Brendan McLellan, January 2005 – (Ph.D. in progress; winner of the Canada Scholarship in the 2005 competition, expected SGS oral by August 2010)

Title: Beasley-Witten localization for  $U(1)$  connections on Seifert manifolds

Kathleen Smith, January 2007 – (Ph.D. in progress, joint with Yael Karshon)

Title: The convexity theorem for loop groups

James Uren, June 2005 – (Ph.D. in progress)

Title: Toric varieties associated to moduli spaces of flat connections on Riemann surfaces

Masrour Zoghi, member of Ph.D. examining committee (April 2010)

Dmitry Donin, member of Ph.D. examining committee (May 2008)  
Andras Asztalos, 1999 -2000– (Ph. D. studies discontinued September 2000)  
Peter Bubenik, member of Ph.D. examining committee (July 2003)  
Eugenia Soprounov, member of Ph.D. examining committee (June 2002)  
Ivan Soprounov, member of Ph.D. examining committee (June 2002)  
Jason Zimmerman, member of Ph.D. examining committee (July 2002)  
Zohreh Shahbazi, 2001–2004, member of Ph.D. examining committee (July 2004)

(ii)(c) Doctoral students for whom I am on the committee (2011):

Michael Bailey  
Trefor Bazett  
David Bland  
Karene Chu

(iii) *Postdoctoral fellows* (supported in part by my operating grants):

1995-6: Eyal Markman (now Associate Professor, Univ. of Massachusetts at Amherst)  
1996-7: Tadashi Tokieda (now Lecturer, University of Cambridge)  
1996-8: André Lebel  
1999-2001: Dmitry Novikov  
1999-2002: Steven Lillywhite  
2001-2: Bernard Wagneur  
2002-3: Henrique Bursztyn (now Professor, IMPA, Brazil)  
2002-3: Augustin-Liviu Mare (now Associate Professor, University of Regina)  
2002-4: Martin Pinsonnault (now Assistant Professor, University of Western Ontario)  
2003 –6: Megumi Harada (now Assistant Professor, McMaster University)  
2003–5: Ruxandra Moraru (now Assistant Professor, University of Waterloo)  
2003–5: Anne-Laure Biolley  
2003–5: Robert Wendt  
2004–5: Matthieu Willems  
2004–5: Marco Gualtieri (NSERC postdoc, Fields Institute) – now Assistant Professor, University of Toronto)  
2003–6: Alistair Savage (NSERC postdoc, Univ. of Toronto) – now Assistant Professor, University of Ottawa)  
2004–6: Nan-Kuo Ho (NSERC postdoc, Fields Institute) (now Associate Professor, National Tsing-Hua University, Taiwan)  
2004–6: Alex Yong (NSERC postdoc, Fields Institute) (now Assistant Professor, UIUC)  
2004 (September–December): Kevin Purbhoo (NSERC postdoc, University of Toronto. (Assistant Professor, University of Waterloo, July 2007 – present)  
2005 –6, 2007–9: Johan Martens  
2005–8 Yi Lin (now Assistant Professor, Georgia Southern University)  
2006–7 Matthieu Willems (now Instructor, CEGEP Andre Laurendeau, Montreal)  
2007–10 Fabian Ziltener  
2008–10 Alfonso Gracia-Saz  
2009-10 Alejandro Cabrera

## 12d. Other teaching and lectures

1. CIRM, Luminy (France), July 1999: “Hamiltonian group actions” (five expository lectures).
2. IAS/Park City Mathematics Institute, July 1997: “Hamiltonian group actions and symplectic reduction” (five expository lectures).  
These lectures were aimed at graduate students in geometry.
3. University of Illinois at Urbana (Mathematics in Science and Society lecture series), April 1996, lecturer: “Applications of quantum field theory to geometry”.  
This lecture series is aimed at building interactions between mathematics and other scientific disciplines. Previous speakers this year had included Roger Penrose.
4. University of Adelaide, Australia (Conference on Geometry and Topological Field Theory), August 1995, lecturer: “A mathematician’s perspective on topological field theory” (two expository lectures).  
The conference was largely attended by physicists, and was aimed at fostering exchange of ideas between physicists and mathematicians. Five expository lectures were given by a theoretical physicist, as well as four lectures (from a mathematical point of view, but aimed to be accessible to physicists) given by mathematicians. (The two additional mathematics lectures were given by my collaborator F. Kirwan.)
5. Odense University (Summer School on Geometry and Physics), July 1995, lecturer: “Quantum field theory, equivariant cohomology, symplectic geometry and moduli spaces of vector bundles on Riemann surfaces” (four expository lectures).  
The Odense summer school for Ph.D. students in geometry ran for one week in July 1995: five expository lecture courses (each with four lectures) were given, with an audience of 50 Ph.D. students and 20 senior participants. The summer school preceded a large research conference in Aarhus, Denmark which was held the following month and was attended by most of the students in the summer school. The lecture notes of my course were distributed at the time and are being published.
6. Park City-IAS Regional Geometry Institute (IAS, Princeton, NJ), Mentoring Program for Women Mathematicians, May 1994, senior participant and lecturer: “Symplectic geometry and circle actions”.  
The Park City-IAS Mathematics Institute (which evolved from the Regional Geometry Institute, see below) is a summer mathematics research program. It is preceded by a mentoring program (organized by Karen Uhlenbeck and Chuu-Lian Terng) for the women who participate at the graduate student level: ten senior women mathematicians provide mentoring, which involves informal advising and one formal expository lecture as well as an additional informal workshop lecture.
7. NSF Regional Geometry Institute (Park City, Utah), July 1991, postdoctoral participant: led Research Workshop on Chern-Simons gauge theory.  
The NSF Regional Geometry Institute is a one-month mathematics research program organized annually by the NSF; it involves participants at all levels (senior researchers, postdoctoral fellows, graduate students, undergraduates and secondary school teachers). The senior researchers give lecture courses on research areas of current inter-

est (designed for the postdoctoral participants and graduate students, and involving homework exercises); at the same time, more informal workshops on recent research are organized, again accessible to the participants at the postdoctoral and graduate student levels. I was the organizer of one of the three or four research workshops: the topic was Chern-Simons gauge theory, a subject of intense recent research interest which was strongly related to the topic of my doctoral dissertation.

## **E. Administrative Positions.**

August 2010 Chair, SGS examination, Mitch Thomson (Ph.D. candidate, Department of Physics)

2010-11 Associate Chair, Mathematics and Statistics, UTSC

2010-11 Awards committee, Mathematics Dept.

2010-11 Graduate committee, Mathematics dept.

2010-11 Appointments Committee, CMS, UTSC (CLTA position)

2010-11 Tricampus Search Committee, Mathematics Dept. (UTM mathematics position)

2009-10 Tricampus Search Committee, Mathematics Dept.

2009-10 Graduate Committee, Mathematics Dept.

2008-9: Mossman Chair committee, Department of Mathematics

2006-7:

Appointments committee, Department of Mathematics

Promotions committee, Department of Mathematics

Reading committee, Kentaro Hori, for tenure procedure, Department of Physics, University of Toronto

Search committee, Chair, Department of Computer and Mathematical Sciences, UTSC

Search committee, Chair, Department of Mathematics, University of Toronto

2005-6 Selection committee for Principal's Research Award, UTSC

2005-6 Search committee for CLTA, UTSC

2005-8 Decanal promotions committee

2005 (May) Set topology qualifying examination (jointly with Paul Selick)

2004 - Mentor, Kentaro Hori (Department of Mathematics and Physics)

July 2004, wrote report on Kentaro Hori's research for third year review, Department of Physics

May 2004, Chair of Ph. D. thesis senate oral examination (Blas Melissari, Materials Science).

March 2004-June 2004 Search committee, Chair of Computer and Mathematical Sciences, UTSC

October 2003-July 2004 Planning committee (St. George Pure Mathematics)

October 2003-December 2003 Science renovation committee, UTSC

June 2003, Tenure Committee, Department of Mathematics, University of Toronto (Grigory Mikhalkin)

October 2002-April 2003 Search committee, Chair of Computer and Mathematical Sciences, UTSC

October 2002– April 2003 Search committee, Principal, UTSC  
 October 2002 – Appointments Committee (St. George Pure Mathematics)  
 October 2002 – Colloquium Committee  
 April 2002, Appointments Committee (joint Computer Science and Statistics, CRC chair),  
 Dean’s Representative.  
 December 2001, Teaching Committee (for Promotions Committee for Boris Khesin)  
 October 2001-April 2002 Appointments Committee (UTSC Pure Mathematics)  
 May-June 2001, Tenure Committee, Department of Physics, University of Toronto (Yong  
 Baek Kim)  
 July 2000, Chair of Ph. D. thesis senate oral examination (J. Kuang, ECE)  
 October 2000-June 2004 Council (Mathematics Department, University of Toronto)  
 October 2000-, Appointments Committee (St. George Pure Mathematics)  
 October 2000-April 2002, Appointments Committee (joint with Physics)  
 October 2000-Jan 2001, Colloquium Committee  
 October 2000-, Appointments Committee (Computer Science, principal’s representative and  
 dean’s representative)  
 October 1999-September 2000, Appointments Committee (UTSC)  
 October 1999-September 2000, Appointments Committee (joint with Physics)  
 October 1999-September 2000, Appointments Committee (St. George), Applied Math  
 October 1999-September 2000, Appointments Committee (St. George)  
 October 1999-September 2000, Colloquium Committee (chair)  
 October 1998-September 2000, Graduate Committee  
 October 1998-January 1999, Chair Search Committee  
 October 1998-September 1999, Colloquium Committee  
 October 1998-September 1999, Appointments Committee (joint with Computer Science)  
 October 1998-September 2000, Planning Committee  
 December 1997, Prodean for McGill University Electrical Engineering Dept. Ph.D. thesis  
 defence (Ross Wagner).  
 September 1997 – Recruitment Committee, Department of Mathematics and Statistics,  
 McGill University.  
 August 1997, External examiner for McGill University Physics Dept. Ph.D. thesis defence  
 (Harold Roussel).  
 Sept. 1995–June 1996 Committee on Graduate Affairs, Dept. of Mathematics and Statis-  
 tics, McGill University.  
 Sept. 1995–June 1996 Ph.D. External Examiners Subcommittee, Dept. of Mathematics  
 and Statistics, McGill University.  
 May 1996, examiner for McGill University Dept. of Mathematics and Statistics Ph.D.  
 qualifying oral exam (Ruxandra Moraru).  
 May 1994, examiner for final year undergraduate comprehensive examinations, Mathematics  
 Dept., Princeton University.  
 1993-4, examiner for Ph.D. qualifying oral examinations for three Princeton University  
 graduate students in the Dept. of Mathematics (Allen Knutson, Livia Oh, Sunita

Vatuk).

*13b. positions held and service on committees and organizations outside the university of scholarly and academic significance.*

2010-11 Invited to serve on selection committee for Killam Research Fellowships (declined)  
2010-11 Invited to serve on selection committee for E.W.R. Steacie Memorial Fellowship  
(indicated I would be willing to do this in a later year when I am no longer Associate  
Chair at UTSC)  
January 2011, wrote letter recommending Alina Marian for tenure at Northeastern Univer-  
sity  
February 2009, wrote letter recommending Nan-Kuo Ho for appointment as Associate Pro-  
fessor at National Tsing-Hua University, Taiwan  
November 2008, wrote letter recommending Brian Hall for promotion to full professor (Notre  
Dame University)  
January 2007 – wrote letter recommending Indranil Biswas for promotion to Associate  
Professor H (TIFR)  
March 2007 – wrote tenure letter for Melissa Liu (Columbia University)  
January 2006– December 2008 CMS Research Committee, member,  
January 2006 – January 2009 AMS Program Committee for National Meetings, member,  
2005 – asked to be part of selection committee for Veblen Prize (AMS) – declined  
January 2006 – December 2008, CMS Research Committee, Member  
January 2006 – February 2009, AMS Program Committee for National Meetings, Member  
2006, asked to comment on file for promotion to full professor of Eric Zaslow (Northwestern)  
– declined  
January 2005 – spring 2008 BIRS Advisory Panel, member  
January 2005 – spring 2008 BIRS Scientific Advisory Panel, Member  
January 2005- December 2007 Canadian Association for Physics – Committee to select  
winner for annual CAP-CRM Prize  
2005-6, wrote letter supporting promotion to full professor of Eugene Lerman (UIUC)  
2005-6, wrote letter supporting tenure file for Young-Hoon Kiem (Seoul National Univer-  
sity)  
January 2004 – December 2007, Canadian Mathematical Society Nominating Committee,  
member  
2004-2005, wrote letters on tenure files for the following individuals: Maxim Braverman  
(Northeastern), Philip Foth (Arizona), Allen Knutson (University of Michigan)  
January 2003 – present AARMS Scientific Review Panel  
January 2003 – present Encyclopedia of Mathematical Physics, member of Editorial Advi-  
sory Board  
January 2003 – Encyclopedia of Mathematical Physics, member of Editorial Advisory Board  
November 2003 – Fields Institute Fellows Selection Committee  
February 2001– January 2009 Transactions of Amer. Math. Soc., Editor;  
2002-3, external examiner for Ph.D. of Sebastien Racanière (Université de Strasbourg)

2002-3, asked to comment on tenure file for the following individuals: Jonathan Weitsman (Cornell University), Chris Woodward (University of Michigan).

2001-2, asked to comment on tenure files for the following individuals: Hans Boden (McMaster), Yael Karshon (Hebrew Univ. at Jerusalem) Michael Thaddeus (Duke), Siye Wu (Univ. of Colorado),

October 2000, selected as external examiner for McGill University doctoral dissertation (Ruxandra Moraru; for administrative reasons, in the end Prof. Steven Boyer was the external examiner rather than myself, but he made use of the report I had submitted)

March 2001 – December 2004 Fields Institute Scientific Advisory Panel

June 2000 -June 2003 Canadian Mathematical Society, Committee on Endowment Fund

May 2000, external examiner for Yale University doctoral dissertation (Young-Hoon Kiem)

December 1999- June 2003 Canadian Mathematical Society, Board of Directors

January 1999- December 2001 – American Mathematical Society, Nominating Committee.

January 1997 –December 1999 – NSERC Council member.

January 1997 - December 1999 – Canadian Mathematical Society, Committee on Women in Mathematics.

September 1997- June 1998 – Comité de gestion, Institut des Sciences Mathématiques, Montréal.

September 1997- June 1999 – Bureau de direction, Centre de Recherches Mathématiques, Université de Montréal.

May 1996 – external examiner for MIT doctoral dissertation (Allen Knutson).

## **F. Other Relevant Information.**

### *1. Organization of conferences*

Co-organizer (with Xiaonan Ma and Michèle Vergne) of conference “Geometric quantization in the noncompact setting” at Oberwolfach, Germany (February 2011)

Co-organizer (with Tony Bahri and Paul Selick) of Ontario Topology Seminar, Fields Institute, July 2007

Co-organizer (with Megumi Harada, Gerda de Vries, Laura Scull, Ping Zhou) of CWIMAC workshop, Fields Institute, December 7-8, 2006

Co-organizer (with Megumi Harada, Alistair Savage and Alex Yong) of Workshop on Schubert Varieties (Fields Institute, June 8-12, 2005)

Co-organizer (jointly with B. Khesin and R. Myers) of Special Session on String Theory and Integrable Systems, Canadian Mathematical Society Summer Meeting, University of Waterloo, June 2005

Co-organizer (jointly with T. Holm, Y. Karshon, E. Lerman, E. Meinrenken) of Workshop on Moment Maps in Different Geometries (BIRS, Banff, Alberta, May 2005)

Co-organizer of Thematic Year on Geometry and String Theory (2004-5), Fields Institute (jointly with K. Hori, M. Kapranov, B. Khesin, R. Myers and A. Peet)

Co-organized Special Session on Symplectic Geometry, Canad. Math. Soc. Winter Meeting, University of Ottawa, December 2002 (jointly with E. Meinrenken).

Co-organized program on symplectic geometry, Fields Institute, January-June 2001 (jointly with B. Khesin and E. Meinrenken).

Co-organized Special Session on Hamiltonian Systems at American Mathematical Society Sectional Meeting, University of Toronto, September 2000 (jointly with V. Jurdjevic and B. Khesin).

Organized Session on Symplectic Geometry at Canadian Mathematical Society Summer Meeting, McMaster Univ., Hamilton, ON, June 2000.

Organized workshop at CRM, Université de Montréal (September 1999): title “Aspects of Quantization”.

Organized Special Session on Integrable Systems at AMS Meeting, SUNY at Buffalo, jointly with M. Audin (April 1999).

Organized Special Session on Symplectic Geometry and Differential Topology at AMS Meeting, Université de Montréal, jointly with J. Hurtubise and F. Lalonde (September 1997).

Organized Special Session on Symplectic Geometry and Moduli Spaces at AMS Meeting, University of Maryland, jointly with E. Markman (April 1997).

Organized Conference on Symplectic Geometry and Geometric Quantization (CIRM, Luminy, France) jointly with M. Duflo and M. Vergne (July 1996).

November 1994, Isaac Newton Institute for Mathematical Sciences (Cambridge, UK), Workshop on Applications of Symplectic Geometry: organizer.  
I was the sole organizer of this workshop, which had about 40 participants and ran for two weeks. Four of the speakers gave minicourses of two or three lectures to introduce a research area to a broader audience, while most lectures were research lectures. A small number of graduate students participated, and a graduate student seminar (in which these students gave presentations) was organized.

### *2. Organization of seminars*

2002-3, co-organizer of weekly Symplectic Geometry Seminar, University of Toronto, jointly with H. Bursztyn and E. Meinrenken.

1999-2000 co-organizer of biweekly Graduate Symplectic Geometry seminar

1998-2002, co-organizer of weekly Symplectic Geometry Seminar, University of Toronto, jointly with B. Khesin and E. Meinrenken.

1995-6, organizer of Geometry and Topology Seminar, Concordia-McGill-Université de Montréal-UQAM. (This weekly seminar is joint between the four universities.)

1993-4, organizer of Symplectic Manifolds Seminar, Department of Mathematics, Princeton University. (This seminar met weekly.)

### *3. Other:*

1. The paper “Localization for nonabelian group actions” (joint with F. Kirwan) was the subject of a lecture by F. Kirwan at the International Congress of Mathematicians, August 1994.