

# Abraham D. Smith, PhD

227 Jarvis Hall Science Wing  
UW-Stout, 410 10th Ave E  
Menomonie, WI 54751-2506

+1 (715) 232-2655  
[smithabr@uwstout.edu](mailto:smithabr@uwstout.edu)  
<http://www.curieux.us/abe>

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## Experience

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AUGUST 2015 — ONGOING

University of Wisconsin-Stout

### Assistant Professor

Tenure-track faculty in the Department of Mathematics, Statistics and Computer Science and at UW-Stout, Wisconsin's Polytechnic University. Extending geometric research expertise into effective data analysis. Focusing on individualized student development and mentorship with 24 credit teaching load.

AUGUST 2015 — ONGOING

Geometric Data Analytics, Inc.

### Senior Mathematician and Scientific Programmer

Producing commercial-quality software for analyzing big data. Developing new geometric and topological methods for machine learning and pattern recognition.

SEPTEMBER 2011 — JULY 2015

Fordham University

### Peter M. Curran Visiting Assistant Professor

Performed full-time faculty duties, including 3+2 teaching load, student mentoring, active participation in department committees, curriculum development, and technical infrastructure development. Directing undergraduate research in differential geometry, moving frames, and computational methods. Research students: Kathleen Toth and Meredith Lukas.

AUGUST 2009 — MAY 2011

McGill University

### MSRI/NSF Postdoctoral Fellow

Continuing research on the geometry of integrable systems and conservation laws, particularly using the techniques of exterior differential systems. Supported by an NSF All-Institutes Postdoctoral Fellowship administered by the Mathematical Sciences Research Institute through its core grant DMS-0441170. Mentored by Niky Kamran and hosted by the Department of Mathematics and Statistics at McGill University.

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## Education

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MAY 2009

Duke University

### Doctor of Philosophy (Mathematics)

*Integrability of Second-Order PDEs and the Geometry of  $GL(2)$ -Structures*

Directed by Robert L. Bryant. In December 2004, received Master of Arts in Mathematics during PhD program.

MAY 2003

University of Wisconsin-Madison

### Bachelor of Science

Majors in Mathematics and Physics, with honors in Mathematics.

Participated in NSF VIGRE undergraduate research programs directed by James Propp (2001, 2002) and Dan Knopf (2003).

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## Research Interests

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Topological Data Analysis, Scientific Computing, Integrable Systems, Geometry of PDEs Mathematics Education.

In applied mathematics, I develop fast, stable algorithms for data analysis that rely on topological and geometric methods. In pure mathematics, I am particularly interested in developing local differential geometry (in the sense of Élie Cartan) and in the applications of these techniques to integrability phenomena appearing in physical systems, from theoretical and computational perspectives. My work emphasizes the links between commutative algebra, the structure theory of Lie pseudogroups, and the micro-local geometry of the characteristic variety of PDEs.

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## Publications and Preprints

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OCTOBER 2016 *Supervised Learning of Labeled Pointcloud Differences via Cover-Tree Entropy Reduction*. with P. Bendich, J. Harer, and J. Hineman. [arXiv:1702.07959](https://arxiv.org/abs/1702.07959) [cs.LG] A new, fast algorithm for distinguishing multiple samples from an underlying distribution.

SEPTEMBER 2016 *Exterior Differential Systems, from elementary to advanced*. ([arXiv:1701.04930](https://arxiv.org/abs/1701.04930) [math.DG]) A monograph in preparation for Banach Centre Publications covering a computational, algebraic approach to studying differential equations.

JULY 2015 *Constructing Involutive Tableaux with Guillemin Normal Form*. (*Symmetry, Integrability, and Geometry: Methods and Applications*. Vol 11, 053) [arXiv:1410.7593](https://arxiv.org/abs/1410.7593) [math.AP]

OCTOBER 2014 *Degeneracy of the Characteristic Variety*. [arXiv:1410.6947](https://arxiv.org/abs/1410.6947) [math.AP].  
(Under review at [Communications in Analysis and Geometry](#).)

AUGUST 2014 *What is Guillemin normal form?* [[preprint](#)]

AUGUST 2012–ONGOING *Symbol*, software for working with Exterior Differential Systems in the Sage computer algebra system. Code development at [bitbucket.org/curieux/symbol\\_sage](http://bitbucket.org/curieux/symbol_sage)

OCTOBER 2010 *A Geometry for Second-Order PDEs and their Integrability, Part I*. [arXiv:1010.6010](https://arxiv.org/abs/1010.6010) [math.DG]

JANUARY 2010 *Integrable  $GL(2)$  Geometry and Hydrodynamic Partial Differential Equations* (*Communications in Analysis and Geometry* Vol 18 No 4, 2010) [arXiv:0912.2789](https://arxiv.org/abs/0912.2789) [math.DG]

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## Conferences Organized

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JULY 2013 Dalhousie University  
**Pseudogroups and their Applications**  
A special session at the Summer Meeting of the Canadian Mathematical Society. Joint with Francis Valiquette.

JULY 2011 Centre de Recherches Mathématiques  
**Moving Frames in Geometry**  
A week-long workshop at CRM and Université de Montréal, drawing worldwide experts in moving frames. Joint with Francis Valiquette.

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## Student Projects Mentored

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SUMMER 2013 *Moment Maps, Moving Frames, and Computer Vision*. A collaborative research project with undergraduate Meredith Lukas studying the application of Fels–Olver moving frames for computer vision. Funded by a Clare Boothe Luce fellowship.

SUMMER 2013 Mentored three advanced math majors, in preparation for their move to graduate school, through a twice-weekly seminar series with lectures and exercises in representation theory of Lie algebras and applications to differential geometry.

SUMMER 2012 *Curve Optimization in Finsler/Randers geometry*. A collaborative research project with undergraduates Kathleen Toth and Meredith Lukas addressing the question “Can computers draw splines in non-Riemannian geometries?” Funded by Clare Boothe Luce fellowships.

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## Research Talks

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- MAY 2017 U. Minnesota & Institute for Mathematics and its Applications  
**Data Analysis Seminar**  
*Using Cover-Trees and Friends for Machine Learning with the CDER Algorithm*
- FEBRUARY 2017 North Carolina State University  
**Geometry and Topology Seminar**  
*Understanding Integrability via Characteristic Varieties and their Secants*
- OCTOBER 2016 University of St. Thomas  
**AMS Sectional Meeting**  
*Progress Toward a Moduli Theory of Involutive Differential Equations.*
- SEPTEMBER 2016 IMPAN/Banach Centre  
**Warsaw**  
*Advanced Topics in Exterior Differential Systems.* 3.5-hour lecture series.
- DECEMBER 2015 University of Minnesota  
**Math-Physics Seminar**  
*How to Build Involutive PDEs.*
- MAY 2015 University of Wisconsin-Stout  
**Department Colloquium**  
*Local Geometry and Differential Equations*
- MAY 2015 CyberOptics Corporation, Minneapolis, Minnesota  
**Science and Technology Talk Series**  
*Least Angle Regression in Compressed Sensing*
- MAY 2015 City University of New York, Graduate Center  
**Kolchin Seminar in Differential Algebra**  
*The Variety of Involutive Differential Systems via Guillemin Form* [[video](#)]
- MARCH 2015 City University of New York, Bronx Community College  
**Department Colloquium**  
*Solving PDEs with almost-commuting matrices* An overview of the geometric meaning of Guillemin normal form.
- FEBRUARY 2015 San José State University  
**Department Colloquium**  
*Local Geometry and Differential Equations*
- JANUARY 2015 San Antonio, Texas  
**AMS/MAA Joint Meetings**  
*Degeneracy of the Characteristic Variety and Canonical 1-forms on Involutive PDEs.* Part of the special session Geometries Defined by Differential Forms.
- DECEMBER 2014 City University of New York, Graduate Center  
**Geometric Analysis Seminar**  
*Reducing PDEs with Degenerate Characteristic Variety.*
- SEPTEMBER 2014 Fordham University  
**Analysis Seminar**  
*How to cheat at solving PDEs.* Explicit calculations with Guillemin Normal Form allow us to construct involutive PDEs.

- DECEMBER 2013 Fields Institute  
**Workshop on Exterior Differential Systems and Lie Theory**  
*Towards Generalized Hydrodynamic Integrability via the Characteristic Variety*  
 A talk for specialists about using the rank-one and characteristic variety to uncover sub-classes of involutive Lie pseudogroups. [video]
- NOVEMBER 2013 Fordham University  
**Analysis Seminar**  
*Exterior Differential Systems as Generalizations of Partial Differential Equations* A two-lecture series introducing differential ideals, involutivity, and prolongation.
- AUGUST 2013 Colorado State  
**SIAM Conference on Applied Algebraic Geometry**  
*Analysis of Symbols and Tableaux, with Sage*
- JULY 2013 Estes Park, Colorado  
**New Directions in Exterior Differential Systems**  
*Hydrodynamic Exterior Differential Systems and Applications to Pseudogroup Structures*  
 A conference in honor of Robert Bryant's 60th birthday.
- JUNE 2013 Dalhousie University  
**Summer Meeting of the Canadian Mathematical Society**  
*Tableaux of PDE systems and associated Lie pseudogroups.* Part of the special session Pseudogroups and their Applications.
- APRIL 2011 University of Arkansas  
**Conformal Differential Geometry and Representation Theory**  
*Intrinsic Geometry of Second-Order PDEs*  
 Part of the [Spring Lecture Series](#) focused on work of Mike Eastwood.
- FEBRUARY 2011 Fordham University  
**Department Seminar**  
*Intrinsic Geometry for Second-Order Partial Differential Equations*
- NOVEMBER 2010 Texas A&M University  
**Geometry and Analysis Seminar**  
*New G-Structures for the Study of Hyperbolic PDEs*
- AUGUST 2010 Brno, Czech Republic  
**Differential Geometry and its Applications**  
*A New Geometric Framework for Hydrodynamic Integrability.* Part of the programme session Natural Operations and General Geometric Structures.
- APRIL 2010 Macalester College  
**AMS Central Sectional Meeting**  
*A [Proposed] Framework for Hydrodynamic Integrability.* Part of the special session Geometric Flows, Moving Frames and Integrable Systems.
- SEPTEMBER 2009 Université du Québec à Montréal  
**CRM Geometry & Topology Seminar**  
*Integrability of 2nd order PDE and the geometry of GL<sub>2</sub>-structures*
- APRIL 2009 NC State University  
**AMS Southeastern Sectional Meeting**  
*A classification for 2nd order PDEs with GL(2,R) geometry* Part of the special session Geometry of PDE.

- JANUARY 2009 Washington DC  
**AMS/MAA Joint Meeting**  
 Panel member for *Beyond T.A. Training: Calculus Curriculum Development by Graduate Teaching Assistants*
- OCTOBER 2008 Duke University  
**Geometry Forum**  
*Lie algebroids and integrability theorems*
- OCTOBER 2007 University of California, Berkeley  
**Geometry Seminar**  
*GL(2,R) structures and integrability*
- APRIL 2007 Duke University  
**Geometry Forum**  
*Finsler geometry and the technique of moving frames*

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## Talks for Students

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- DECEMBER 2013 Fordham University  
**Fordham Math Club**  
*The Algebra of Data* A talk for undergraduates introducing the algebra of patches, data entropy, and cryptographic hash functions.
- MAY 2013 Fordham University  
**Fordham Math Club**  
*How to Count* A talk for undergraduates introducing the Orbit-Stabilizer Theorem and Burnside's Lemma.
- FEBRUARY 2012 Fordham University  
**Fordham Math Club**  
*What is d?* A talk for undergraduates introducing the idea of differential forms, the Poincaré Lemma, and its influence on topology.
- NOVEMBER 2007 Duke University  
**Graduate/Faculty Seminar**  
*DEs to EDS: How to "solve" PDEs without being clever*

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## Teaching Experience

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- FALL 2015 — ONGOING University of Wisconsin-Stout  
**General Courses**  
 Teaching **all** levels of undergraduate courses, including College Algebra, Calculus I, Linear Algebra, and Differential Equations, graduate Scientific Computing, and independent studies. Overall teaching load 24 credits per year.
- FALL 2011 — SPRING 2015 Fordham University  
**General Courses**  
 Teaching **all** levels of undergraduate courses, including PreCalculus, Finite Mathematics, Calculus I, Calculus II, Multivariable Calculus, Linear Algebra I, and Linear Algebra II. Overall teaching load 5 courses per year.  
 Acting Course Director for PreCalculus.
- SPRING 2015 Fordham University  
**Programming for Mathematics and Science**  
 Designing and teaching **new** 2nd-year course on using Python to develop algorithms for real-world scientific data analysis. Co-Teaching with Prof. Papadakis from Computer and Information Sciences.

FALL 2013 AND 2014 Fordham University  
**Seminar in Scientific Communications**  
Teaching 3rd-year course on both oral and written scientific exposition, technical writing and editing, and beginner-to-advanced use of  $\text{\LaTeX}$ .

FALL 2012 Fordham University  
**Advanced Topics Course: Differential Geometry**  
Designed and taught a **new** senior-level course covering the elements of Riemannian Geometry for mathematics and physics majors.

FALL 2011 McGill University  
**Mentor**  
Helped train McGill PhD candidate Sara Froehlich in exterior differential systems, and served as minor-topic chair on her Preliminary Examination committee.

FALL 2005—SPRING 2009 Duke University  
**Calculus Teacher**  
Lecturer for a total of five 30-students sections of Math 32 (Calculus II) or Math 32L (Lab Calculus II) over four semesters.

FALL 2008 Duke University  
**Course Supervisor**  
Course Supervisor for three sections of Math 41L (Lab Calculus II for entering freshmen). Lecturer for one 30-students section. Lab Instructor for two sections. This was the first full run of a course that I helped design.

SUMMERS 2006 & 2007 Duke University  
**Pre-Qual Instructor**  
One of two instructors for Pre-Qualifier Preparation Program, a week-long intensive linear-algebra and analysis review for incoming graduate students.

SUMMER 2005 Duke University  
**TIP Topology Mentor**  
Solely developed and taught a 4-week course on the algebraic topology of surfaces as a special program for three extremely bright teenage students in Duke's Talent Identification Program.

FALL 2004 Duke University  
**Lab Instructor**  
Lab instructor for one 30-student section of Math 32L (Lab Calculus II).

FALL 2002 & SPRING 2003 University of Wisconsin  
**Teaching Assistant**  
Teaching assistant for two sections each of Math 221 and 222 (Calculus and Analytic Geometry I and II).

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## Curriculum Development

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SPRING 2017 University of Wisconsin-Stout  
**Machine Learning**  
Designed a course on machine learning, to support a concentration in data science for Applied Mathematics and Computer Science students.

FALL 2014 Fordham University  
**Pre-Calculus Course Management**  
At the request of the Mathematics Department Chair, regularly meeting with all instructors of Pre-Calculus to ensure course quality and consistency during period of increased enrollment.

FALL 2012–ONGOING Fordham University  
**Electronic Teaching Resources**  
Built and maintain Sage Notebook server and MAA WebWork server for projects and homeworks throughout the Mathematics department. Joint with Shaun Ault and Jay Hineman.

SPRING 2012 Fordham University  
**Pre-Calculus Course Improvement**  
Re-designed Pre-Calculus course to better match current student population, in consultation with Prof. Maryham Hastings and the Gabelli School of Business. Produced guidelines and suggestions to ease the burden on adjunct teaching faculty and to improve consistency across different sections and teachers.

FALL 2008 Duke University  
**Electronic Teaching Resource**  
Under a teaching mini-grant from the Duke Graduate School, developed an on-line repository called “TRAP” for worksheets, quizzes, and tests using MySQL, Python, Django, and Javascript. Joint with Rann Bar-On.

SPRING 2008 Duke University  
**Curriculum Improvement**  
Updated labs and teaching materials for experimental course, Math 41L.

SPRING 2007 Duke University  
**Calculus Curriculum Review**  
Helped organize and participated in a graduate student review of the calculus curriculum. The main result was a completely new course, Math 41L, for which we designed a complete syllabus, including textbook selection, homework lists, and lab creation. Full report: [www.curieux.us/abe/proposal.pdf](http://www.curieux.us/abe/proposal.pdf)

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## Professional Service

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2010–ONGOING **Referee and Reviewer**  
Referee for journals such as *Selecta Mathematica*, *Journal of Differential Geometry*, *SIGMA*, *Communications in Analysis and Geometry*, and *Foundations of Computational Mathematics*. Reviewer for the AMS Mathematical Reviews.

2012–2015 **Designer and Administrator of Research Computing Cluster**  
Designed and maintain a Linux environment for high-performance scientific computation, used by researchers in many departments across the university. The first project of its kind at Fordham, this project was administratively complex: its construction took collaboration with the computing staff, planning discussions the faculty technology committee, and funding approval from the academic deans.

2011–2015 **Undergraduate Curriculum Committee**  
Active member of Fordham Mathematics Undergraduate Curriculum Committee.

2012–2014 **Pi Mu Epsilon Advisor**  
Advisor for Fordham’s chapter of the Pi Mu Epsilon mathematical honor society chapter.

2007 **Committee Secretary**  
Secretary of the Duke Graduate Calculus Curriculum Review Committee, which performed a complete review of the first- and second-year curriculum, redesigned syllabi, selected textbooks, and added new courses.

2006 **Seminar Organizer**  
Duke Graduate Student Geometry Seminar.

2005 **Association President**  
President of Duke Math Graduate Student Association during sensitive compensation, placement, and curriculum disputes with the University.

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## Computer and Technology Skills

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*Languages:* Deep knowledge of L<sup>A</sup>T<sub>E</sub>X, Sage, Python, MAPLE, Javascript, and SQL. Familiarity with many others.  
Can read and interpret any programming language.  
Thorough UNIX/Linux system and network administration experience since 1995.  
IPv6 certification level "sage" from Hurricane Electric.

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## Professional Membership

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American Association for the Advancement of Science [AAAS].  
American Mathematical Society [AMS].  
Mathematical Association of America [MAA].  
Society for Industrial and Applied Mathematics [SIAM].

*Alvin D. Smith*

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Follow hyperlinks for additional information.

April 6, 2017