Department of Applied Mathematics

University of Colorado
at Boulder
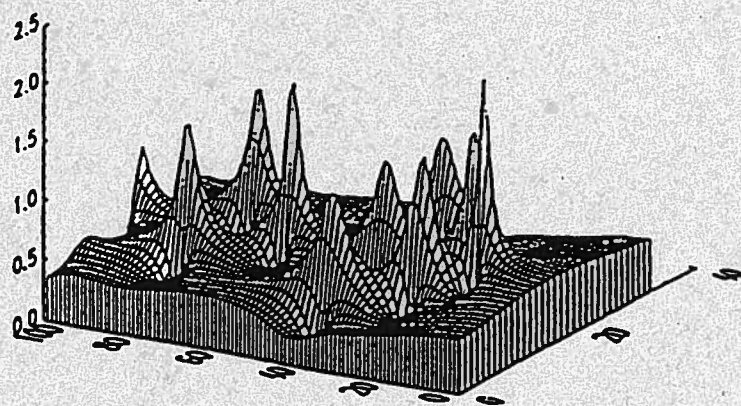
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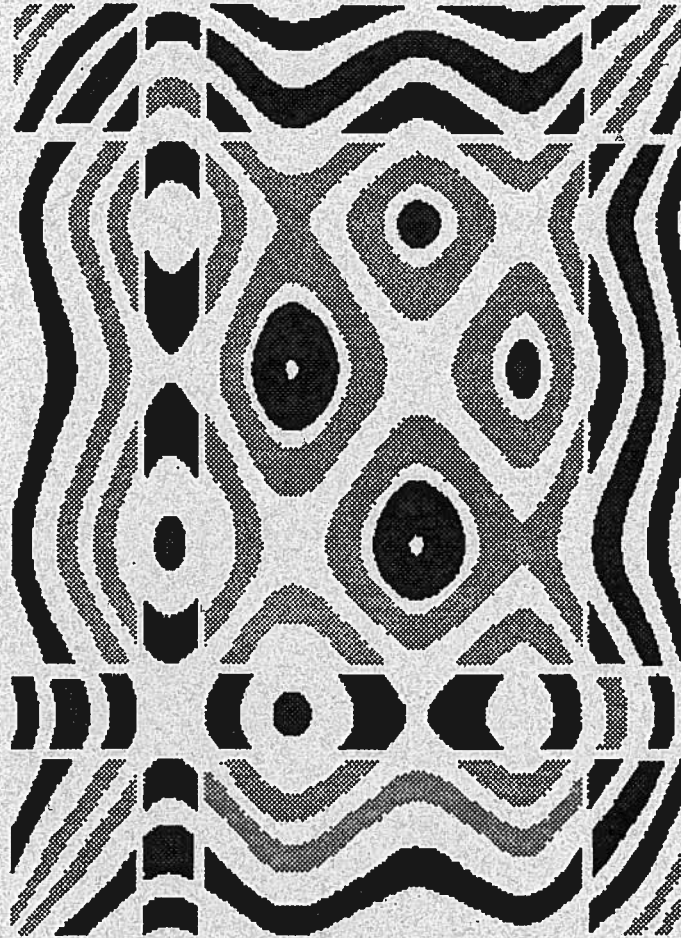
Annual Report

1997-98

Mark J. Ablowitz, Chair

June 30, 1998

VIGRE IS COMING!

PREFACE

From the Chair

The Department of Applied Mathematics (APPM) has completed an extraordinarily successful year. APPM was recently informed that it will be the recipient of a major new grant from the National Science Foundation. The proposal was part of a national competition among mathematical science units in the "VIGRE" (Vertical Integration in Research and Education) program funded by the Division of Mathematical Sciences at NSF. The $2.34 million grant will allow the Department to integrate naturally its teaching and research functions by forming a number of core area tetrahedral groups consisting of faculty, postdoctoral associates, graduate students and undergraduates. The focus of the effort is consonant with the stated aims of the University to promote a total learning environment (TLE) as a critical component of the University's function.

The Department is indebted to Professor James Meiss who as Principal Investigator led the effort in writing the proposal and who coordinated the site review of three NSF program monitors. The Co-PI's on the proposal were M. Ablowitz (Chair), J. Curry (Associate Chair), and B. Fornberg (Chair of the Graduate committee). They worked closely with Professor Meiss in all facets of the proposal and site review. It should be stressed that all members of the Department (faculty, grads, undergrads and staff) made invaluable contributions in one form or another. In a real sense, the VIGRE grant is a major Departmental achievement.

The grant means that APPM is poised to move to the next level of excellence. APPM has demonstrated that it is capable of competing with excellent departments in the mathematical sciences, many of which are much larger and have considerably more resources than we. APPM is looking forward to the challenges that the VIGRE effort presents.

We are also pleased to report a major equipment grant from IBM. During the academic year, 1997-1998, IBM announced that the Applied Mathematics Department was the recipient of a 12-node IBM SP 2 advanced parallel processing computer, valued at nearly $900,000. We give special thanks to IBM for donating this gift to us and to APPM Professors Tom Manteuffel (Principal Investigator) and Steve McCormick who, in collaboration with Professor (and APPM affiliated faculty member) Oliver McBryan, from Computer Science, worked so hard to make this grant a reality. Given the extreme importance of parallel processing in the field of scientific computation, this machine will occupy a centrally important research and teaching function in the Department. This gift from IBM will allow our students and faculty to gain invaluable experience in working with state of the art parallel computers.

Applied Math had additional cause to celebrate this spring with the announcement that Professor Harvey Segur had been selected as a Presidential Teaching Scholar, one of the highest honors the University can bestow. This award is offered to a truly select group of individuals at the University for their remarkable teaching and scholarly efforts. Segur is widely known to be an extraordinary teacher and scholar and was the only recipient of the award this year University-wide. Harvey is the second APPM faculty member to receive this honor joining ranks with Professor James Curry. Congratulations Harvey!

Teaching and research activities of the faculty in the Department continue to be carried out at a daunting level, especially when considering the size of the core faculty (13 tenure track faculty and 2 instructors). In 1997-1998, the Department taught 3,323 students, translating to more than 11,300 student credit hours, all at a level of calculus and above. This is the largest enrollment ever. At the lower division level, the faculty are teaching in excess of 100 students/lecture. We are pleased to report that the Department has successfully introduced computational projects into its second year lower division courses (APPM 2350, Calculus III, and APPM 2360, Introduction to Differential Equations). Based upon student interest, we are expanding our lower division efforts in computing and related projects.

Graduate enrollment has increased to 51 this year, and the number of affiliated faculty has increased to 37. Affiliated faculty can direct graduate students in an MS or PhD degree. These are remarkable figures considering the fact that there were no graduate students or affiliated faculty in 1989, when the independent Program in Applied Mathematics began operations.

The core faculty's research activities are broadly based. This includes service on 19 editorial and advisory boards of journals and periodicals, the publication of 44 articles, and presentation of 49 invited lectures. There were 51 Department of Applied Math preprints during 1997-1998. This brings the total number of articles in the Preprint series to 388 since the founding of the series in 1989!

The undergraduate BS degree has been strengthened by the addition of a financial math option which was offered for the first time in the 1997-1998 academic year. In 1997-1998, APPM graduated 15 BS students, 11 MS and 3 PhD students.

APPM is pleased to welcome Keith Julien as an Assistant Professor of Applied Mathematics. Keith received his PhD in Applied Mathematics from Cambridge University in 1991. Keith worked as a postdoctoral researcher in JILA (1991-1994), was a member of the Advanced Study Program at NCAR (1994-1996) and served as an instructor in Applied Mathematics (1997). Keith's areas of expertise include mathematical and computational fluid dynamics. The addition of Keith Julien to the faculty is a fitting and appropriate capstone to Applied Math's most successful year to date.

From the Associate Chair

The Associate Chair continues to provide coordination and operational support for scheduling, assigning, and implementation of the Department's teaching mission and future development plans and goals. Below we mention a few of the ongoing projects and efforts that we have been engaged in.

With this year's 10% student enrollment increase and subsequent student demand for Applied Mathematics courses, the Associate Chair was able to argue successfully for incremental resources that allowed the Department to meet its teaching obligations. The Department is becoming more data driven and because of this, it is possible not only to respond to near term chaos but also to anticipate longer term trends.

The Associate Chair also coordinated and facilitated the transition to a new computer support model within the Department. While the Department's computing effort is not wholly self-sufficient, it is on the way to achieving this necessary goal. Although the Department made this a major goal for the reallocation process currently taking place within the College of Arts and Sciences, unfortunately our request did not meet with a positive response.

Presentations made to the Undergraduate Committee of the College of Engineering helped convince that group to support the implementation of new student fees for our lower division courses. These new resources will be used to support computer labs and projects in those courses. Further, with the advent of computational projects and labs, teaching assistant (TA) duties for these classes were also revamped. Now a portion of TA duties for these courses includes the development of additional course materials which can be archived and used as needed.

A successful proposal was made to the Student Computing Initiative for the Department's instructional computing laboratory. This means that with the Fall 1998 semester, an important priority for the College of Arts and Sciences will be to find dedicated space and provide equipment for a smart classroom for the Department's lower division instructional needs.

The Associate Chair co-authored a letter to potential majors. Our goal is to increase the number of Applied Mathematics majors. In addition, a plan was initiated to forge stronger links with K-12 partners, so that the Department could develop a formative feedback loop based on assessment. This would lead to counselors and high school mathematics teachers becoming more aware that there are excellent careers available in the mathematical sciences.

All of the efforts mentioned were carried out with the help of faculty, students and staff.

1. ROLE AND MISSION

The objectives of the Department of Applied Mathematics at the University of Colorado at Boulder are summarized below:

a) Provide undergraduate and graduate students with high quality education and training in applied mathematics and prepare them for careers in industry, laboratories and the academic professions;

b) Offer and monitor degree programs leading to a BS, MS and PhD degrees in Applied Mathematics;

c) Nourish and maintain a professional environment in which excellence in teaching, learning, scholarship and creativity are of central importance;

d) Assure teaching and research expertise in a number of key areas of applied mathematics including the methodology of applied mathematics, computational mathematics and algorithms, industrial applications, applied probability and statistics.

2. OVERVIEW

A. Undergraduate Education

In 1997-98, the Department in Applied Mathematics had a core of thirteen tenure track faculty members plus two instructors responsible for the teaching and advising of all undergraduate and graduate students taking applied mathematics courses. The Department has a large teaching commitment since most undergraduate engineering majors are required to take four courses in applied mathematics. The Department taught a total of 3,323 undergraduate and graduate students in 22 undergraduate courses (divided into 56 sections) and 21 graduate courses. We had 44 undergraduate majors with 15 receiving their baccalaureate degrees. We are very proud that 28 made the Dean's List for academic achievement with grade point averages of 3.5 or better. There are also 23 students pursuing a minor in Applied Mathematics in the College of Arts and Sciences.

In the coming years, the VIGRE Grant that the department received from the National Science Foundation, will undoubtedly change the character of our undergraduate major. Undergraduates will have many new opportunities to participate in "tetrahedra" consisting of undergrads, grads, postdocs and faculty working together on many parts of a common research theme. The art of creating and testing mathematical models of important aspects of the world will be increasingly emphasized as part of the undergraduate training. Participation in research seminars and group discussions will broaden the undergraduate experience, making our majors even more competitive when they enter the job market.

B. Graduate Education

The graduate student population continues to grow and the graduate program is prospering. In 1996-97, the Department had 51graduate students represented by nineteen teaching and laboratory assistantships, nine graduate students on fellowships and traineeships, fourteen research assistantships and nine providing their own support. The number of graduate students supported by research grants has increased substantially; this is due in part to the success of our faculty in obtaining research support and to the affiliated faculty program. The Department has 37 affiliated faculty members, each of whom can direct a graduate student towards a PhD in Applied Mathematics. It should be noted that, counter to national trends, we continue to be very successful in recruiting U.S. citizens to study in our graduate program. In 1997-98, 78% of the incoming students with support were U.S. citizens from U.S. undergraduate universities. Among all graduate students in 1996-97, eleven were foreign graduate students and five more will be starting in the fall. Although we certainly encourage international applications, our success in being able to attract high quality American graduate students continues to be remarkable.

This year, 23 students were supported partially or fully by fellowships or grants. The National Science Foundation graduate traineeships supported seven students: Travis Austin, Lora Billings, Anna Bunce, Brian Bloechle, Chris Higginson, Joe Iwanski and Ken Jarman. Michelle Ghrist received partial support from the traineeship grant, complementing her award from the National Physical Science Consortium. The $555,000 NSF traineeship grant provides full support for six predoctoral students over a five year period. In addition, there was one student who was supported by a DOD AASERT Award, David Trubatch (ONR, Prof. Ablowitz). Allison Baker was in her first year of support on a University of Colorado Chancellor's Fellowship. An additional eleven students were supported by faculty or affiliated faculty grants (AFOSR, DARPA, DOE, and NSF).

C. Enrollment Statistics

Enrollment in the courses offered by the Department continues at extremely high levels. It is particularly noteworthy, given the faculty's small size that the Department teaches so many students. The statistics over the past few years are as follows:

Year	total enrollment in courses	Applied Mathematics graduate students	Applied Mathematics undergraduate majors
1990-91	2562	17	45
1991-92	2781	27	50
1992-93	2797	28	47
1993-94	2809	33	47
1994-95	2670	39	51
1995-96	2734	40	54
1996-97	2973	46	52
1997-98	3108/3323*	51	44

*The totals in bold include all Calulus I & II Work Study Groups, as well as Calculus III & Differential Equations Labs.

In 1994-95, we observed a small decrease in enrollment in our lower division courses due to smaller enrollment in Engineering. However, enrollment in our upper division courses has continued to increase. Enrollment was up in 1997-98, and with projected increases in undergraduate enrollment we foresee significant enrollment increases in applied mathematics courses.

D. Teaching Awards

Faculty in the Department have been honored with distinguished teaching awards. We are extremely pleased to note that Professor Harvey Segur has been named a President's Teaching Scholar in 1998, the highest honor awarded within the university.

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E. Graduates

We would like to congratulate our students who graduated this past year with a degree in Applied Mathematics. They are:

PhD degree

August 1997: Nick Coult

May 1998: Lora Billings, Bernard Deconinck

Master's degree

August 1997: John Carter*, Michelle Ghrist*, Ken Jarman*

May 1998: Slava Akmaev*, Anna Bunce, Andrea Codd*, Tony Edgin*, Chris Higginson*, Youn-Hee Lim, Joe Polacco, Vanessa Robins*

*Continuing with PhD

Bachelor's degree

August 1997: Brad Oedzes, Jeremy Zucker

December 1997: Danielle Bundy, Cristin Dozier, Brett Pontarelli, James Scott, Jack Thiesen

May 1998: Gregg Bachmeyer, Billy Cornell*, Chris Falvey, Geoffrey Hart, Jia Li*, Carolyn Noonan, Joe Pearse, San Pinijchob.

* With Distinction

F. Research

The research activities of the core faculty in the Department are varied. They include nonlinear dynamics, chaos theory, nonlinear waves, solitons and integrable nonlinear evolution equations, nonlinear optics, inverse problems, analysis of nonlinear equations arising in physical phenomena, computational mathematics including wavelet analysis, multigrid, iterative methods and computational fluid dynamics, matrix algebra, applied probability and statistics. Our affiliated faculty are rostered in a wide range of departments and nearby institutions, including Aerospace Engineering; Astrophysical and Planetary Sciences; Chemistry and Biochemistry; Civil Engineering; Colorado School of Mines; Computer Science; Electrical and Computer Engineering; Geological Sciences; Mathematics; Mechanical Engineering; CIRES (Cooperative Institute for Research in Environmental Sciences); INSTAAR (Institute for Arctic and Alpine Research); and the Graduate School of Business.

This report provides data which show that the faculty in the Department are extremely active in their research and scholarly work (a list of publications, invited lectures and Department Preprints is included at the end of this report). However, another very important aspect of the faculty's role in the national and international scholarly effort in applied mathematics is service as editors and advisory board members of archival journals and textbook series. In fact, during 1997-98 the faculty in the Department currently serve in nineteen such capacities on fourteen journals/periodicals which include:

Applied and Computational Harmonic Analysis (Beylkin)
Cambridge University Press Texts in Applied Mathematics (Ablowitz)
Chaos (Ablowitz)
Communications on Applied Nonlinear Analysis (Bebernes, Easton)
Electronic Transactions in Numerical Analysis (Manteuffel)
Inverse Problems (Ablowitz)
Journal of Engineering Mathematics (Ablowitz)
Journal of Numerical Linear Algebra and Applications (Manteuffel)
Physica D (Meiss)
Rocky Mountain Journal of Mathematics (Bebernes)
Springer-Verlag Series in Integrable Systems and Solitons, (Ablowitz)
SIAM Journal of Numerical Analysis (Manteuffel, Beylkin, McCormick)
SIAM Journal on Scientific Computation (McCormick)
Studies in Applied Mathematics (Ablowitz)

In addition, Jim Curry is a member of the board of governors of The Geometry Center, at the University of Minnesota, and Tom Manteuffel is Vice President of the Society of Industrial and Applied Mathematics (SIAM).

G. Conferences

Copper Mountain

The Ninth Annual Copper Mountain Conference on Multigrid Methods was held March 30-April 3, 1998, at Copper Mountain, Colorado. The conference was organized by Tom Manteuffel and Steve McCormick from the Department of Applied Mathematics and Front Range Scientific Computations, Inc., in cooperation with the Society of Industrial and Applied Mathematics and supported by DOE, the GMD, IBM, and NSF. Attendance for this meeting was approximately 100.

Los Alamos Days

Complex Systems and Nonlinear Phenomena

The Department of Applied Mathematics has a tradition of holding a small annual conference jointly with the Center for Nonlinear Studies (CNLS) at Los Alamos National Laboratory, New Mexico, with the venue alternating between Boulder and Los Alamos. In 1998, the conference was held in Boulder.

A few changes from the regular format took place in 1998. We welcomed the participation of the Colorado Center for Chaos and Complexity (C4) in organizing the meeting. Also, the conference was expanded to two and a half days, April 30-May 2.

The purpose of the meeting is to give our graduate students, instructors, postdocs and visitors an opportunity to meet other young scientists in related fields and allow them to present their work before a scientific audience in a less formal setting.

H. Remarks

Faculty member Keith Julien was named Assistant Professor in the Department of Applied Mathematics in 1997.

Anne Dougherty was promoted to Senior Instructor of Applied Mathematics.

3. FACULTY, RESEARCH ASSOCIATES AND STAFF

5. Core Faculty and Long Term Visitors

Mark J. Ablowitz, Chair, Professor; PhD, Massachusetts Institute of Technology. Partial Differential Equations, Solitons, Nonlinear Waves.

Jerrold Bebernes, Professor; PhD, University of Nebraska. Differential Equations, Reaction Diffusion Systems, Combustion Theory, Analysis.

Gregory Beylkin, Professor; PhD, New York University. Computational Methods, Wavelets, Geophysical Inverse Scattering.

Gino Biondini, Postdoctoral Research Associate; PhD, Universita de Perugia, Italy. Nonlinear Waves, Nonlinear Optics.

Marian Brezina, Postdoctoral Research Associate; PhD, University of Colorado at Denver. Algebraic Multilevel Methods.

Nicholas Coult, Postdoctoral Research Associate; PhD, University of Colorado at Boulder. Numerical Analysis, Wavelets, Integral Equations, Eigenvalue Problems.

Robert Cramer, Postdoctoral Research Associate; PhD, University of Colorado at Boulder. Numerical Analysis, Wavelets, Potential Theory

James H. Curry, Professor; PhD, University of California at Berkeley. Dynamical Systems, Numerical Methods, Nonlinear Equations.

David Dean, Postdoctoral Research Associate; PhD, University of Colorado at Denver. Computational Math, Multigrid Analysis.

Anne Dougherty, Senior Instructor; PhD; University of Wisconsin, Madison. Applied Probability, Stochastic Processes.

Tobin Driscoll, Postdoctoral Research Associate; PhD, Cornell University. Numerical Analysis, Numerical Methods for PDEs and Conformal Mapping.

Holger Dullin, Postdoctoral Research Associate; PhD, Universitaet Bremen, Germany. Hamiltonian Systems, Integrable Systems, Semiclassical Quantization.

Robert Easton, Professor; PhD, University of Wisconsin. Dynamical Systems, Hamiltonian Mechanics.

Bengt Fornberg, Professor; PhD, Uppsala University, Uppsala, Sweden. Numerical Analysis, Computations of Wave Phenomena.

David Gines, Postdoctoral Research Associate; PhD, University of Colorado at Boulder.Wavelets and Multilevel Methods, Biomedical Engineering.

Rod Halburd, Postdoctoral Research Associate; PhD, University of New South Wales. Integrable Systems, Darboux-Halphen System.

Scott Herod, Postdoctoral Research Associate, PhD, University of Colorado. Symmetries and Differential Equations.

Keith Julien, Assistant Professor; PhD, Cambridge University. Mathematical and Computational Fluid Dynamics, Dynamical Systems Theory.

Congming Li, Assistant Professor; PhD, New York University. Elliptic Partial Differential Equations.

Hector Lomeli, Instructor; PhD, University of Minnesota. Dynamical Systems.

Tom Manteuffel, Professor; PhD, University of Illinois, Urbana. Computational Math; Numerical Linear Algebra, Iterative Mathematics, Numerical Solution of PDE's.

Steve McCormick, Professor; PhD, University of Southern California. Computational Math, Numerical Partial Differential Equations, Multigrid Methods, Parallel Computation, Computational Fluids, Tomography, Electromagnetics.

James D. Meiss, Professor; PhD, University of California at Berkeley. Dynamical Systems, Hamiltonian Mechanics, Plasma Physics.

Martin Mohlenkamp, Postdoctoral Research Associate; PhD, Yale University. Computational Harmonic Analysis, Non-linear PDEs and Cryptography.

Lucas Monzón, Postdoctoral Research Associate; PhD, Yale University. Harmonic Analysis, Wavelets.

J. Adam Norris, Part-time Instructor; PhD, University of Colorado, Boulder. Phase Change Kinetics, Perturbation Methods, Numerical Methods.

Harvey Segur, Professor; PhD, University of California at Berkeley. Nonlinear Waves, Fluid Dynamics, Asymptotic Methods.

John Williamson, Professor; PhD, University of Minnesota. Statistical Methods in Genetics, Applied Probability, Mathematical Statistics.

B.   Affiliated Faculty--Graduate Department

Steve C. Arendt (Colorado Research Associates), Theoretical Fluid Dynamics

Norm Bleistein (Mathematics, Colorado School of Mines), Direct & Inverse Scattering, Asymptotic Methods, Wave Phenomena

William Blumen (Program in Atmospheric and Oceanographic Sciences--PAOS), Geophysical Fluid Dynamics in Atmospheric Science

Elizabeth Bradley (Computer Science), Scientific Computation, Artificial Intelligence, Nonlinear Dynamics

Richard Byrd (Computer Science), Numerical Computation, Optimization Algorithms

John Cary (Physics), Nonlinear Dynamics, Plasma Physics, Accelerator and Space Physics

Senarath deAlwis (Physics), Theoretical Physics, String Theory, Quantum Gravity

Thomas DeGrand (Physics), Numerical Methods for Quantum Field Theory

Fred Glover (Graduate School of Business), Large-scale Systems, Applied Artificial Intelligence, Optimization Models

Martin Goldman (Physics), Plasma Physics, Nonlinear Waves, Turbulence

Vijay Gupta (Geological Sciences), Hydrology, Stochastic Processes, Fluid Dynamics

Ute Christina Herzfeld (INSTAAR, Geomathematics), Geostatistical Analysis of Remote Sensing Data, Applications in Glaciology, Marine Geophysics and Global Change Research

Tissa Illangasekare (Civil Engineering), Mathematical Modeling of Flow and Transport in Porous and Fractured Media, Computational Methods, Numerical Modeling

Elizabeth Jessup (Computer Science), Numerical Computation, Parallel Computation

David Kassoy (Mechanical Engineering), Fluid Dynamics, Combustion Theory, Thermal Science

James Kelly (College of Business), Heuristic Search, Optimization, Artificial Intelligence

Manual Laguna (College of Business), Exact and Heuristic Methods for Combinatorial Optimization Problems, Network Flow Programming, Applied Artificial Intelligence

Michael Lightner (Electrical Engineering), VLSI, Discrete Mathematics, Graph Theory

Shankar Mahalingam (Mechanical Engineering) Turbulent Combustion, Direct Simulations

Andrew Moore (Atmospheric and Oceanic Sciences), Ocean-Atmosphere Modeling

Oliver McBryan (Computer Science), Parallel Computation, Graphics and Visualization, Computational Fluid Dynamics

Lev Ostrovsky (CIRES/NOAA Environmental Technology Laboratory), Nonlinear Waves, Fluid Dynamics, Oceanography, Acoustics

Harihar Rajaram (Civil, Environmental and Architectural Engineering), Fluid Flow, Transport Phenomena and Reactive Processes in Geologic/Geochemical Phenomena

John Rundle (Geological Sciences; Cooperative Institute for Research in Environmental Sciences), Statistical Mechanics Applied to Earth Sciences, Complex Systems, Simulations of Nonlinear Systems, Earthquakes, Transport Processes in the Geological Sciences

Robert Sani (Chemical Engineering), Computational Fluid Dynamics, Free and Moving Boundary Problems, Stability of Systems

Duane Sather (Mathematics), Partial Differential Equations, Fluid Mechanics

Robert Schnabel (Computer Science), Numerical Methods for Optimization, Nonlinear Equations, Parallel Scientific Computation

Richard Seebass (Aerospace Engineering), Aerodynamics, Gas Dynamics, Supersonic and Hypersonic Flows

J. Michael Shull (Astrophysical and Planetary Sciences), Theoretical Astrophysics

Rex Skodje (Chemistry and Biochemistry; Joint Institute for Laboratory Astrophysics), Nonlinear Dynamics, Quantum Chaos, Molecular Dynamics

Gary Stormo (Molecular, Cellular and Developmental Biology--MCDB), Molecular Structures and Patterns, Computer Sequence Analysis, Splicing Algorithms

Renjeng Su (Electrical Engineering), Nonlinear Dynamics Modeling, Control, Robotics

Juri Toomre (Astrophysical and Planetary Sciences; Joint Institute for Laboratory Astrophysics), Astrophysics, Mathematical Modeling, Numerical Simulation

Patrick Weidman (Mechanical Engineering), Hydrodynamic stability, solitary waves and their interaction, counter-rotating vortex rings, Stokes flow on dendrite models, similarity flows in natural convection, fluid sloshing in freely suspended containers

Jeffrey B. Weiss (Astrophysical and Planetary Sciences; Atmospheric and Oceanic Sciences), Geophysical Fluid Mechanics, Turbulence, and Climate Predictability

Joseph Werne (Colorado Research Associates), Fluid Dynamics

Ellen Zweibel (Astrophysical and Planetary Sciences), Plasma Physics, Astrophysics

C. Short Term Visitors, 1997-98

Alan Bishop, Los Alamos National Laboratory, Los Alamos, NM, April 30-May 2, 1998

Leonid Bunimovich, Georgia Institute of Technology, January 29-January 31, 1998

Sarbarish Chakravarty, University of New South Wales, Sydney, Australia, December 1997-February, 1998

Silvana Delillo, Universitá de Perugia, Italy, Oct. 4-Nov.9, 1997; May 17-May 31, 1998

Stefka Dimova, University of Sofia, Bulgaria, April 6-April 16, 1998

A.S. Fokas, Imperial College, England, April 15-April 19, 1998

Yasuhiro Fuji, Nagoya University, Japan, February 21-March 6, 1998

Ben Herbst, University of Stellenbosch, South Africa, January – February 14, 1998

Ute Herzfeld, Universität Trier, Germany, March 18-March 28, 1998

Brian Hunt, University of Maryland, February 25-February 28, 1998

Rei Inoue, Nagoya University, Japan, February 21-March 6, 1998

Rich Le Houcq, Sandia National Laboratory, November 3-5, 1997

Sang Dong Kim, Kyungpook National University, Korea, 2/17-3/31, 1998

Tetsuro Konishi, Nagoya University, Japan, March 9-March 20, 1998

Chang-Ock Lee, Inha University, Korea, January 26-February 25, 1998

Paul Milewski, University of Wisconsin at Madison, April 23-April 25, 1998

Christoph Pflaum, Technical University of Würzburg, Germany, March 2 – April 30, 1998

Mary Silber, Northwestern University, Evanston, IL, January 1998

Gerhard Starke, University of Karlsruhe, Germany, March 16-March 29, 1998

Lev Tsimring, University of California at San Diego, February 1998

Miki Wadati, University of Tokyo, Japan, February 21-March 6, 1998

D. Staff

Stu Naegele -- Department Administrator

Margy Lanham -- Professional Research Assistant

Lynn Randolph – Student Services Coordinator

Tiana Baenziger– Faculty Services Coordinator

4. COLLOQUIA, SEMINARS, SYMPOSIA, 1997-98

A. Applied Mathematics Colloquium Schedule, 1997-98

Our Applied Mathematics Colloquium series continued this year. The colloquia were held Friday afternoons during the academic year at 3:00 p.m., with coffee and tea preceding at 2:30 p.m. in the APPM conference room, ECOT 226.

Warren MacEvoy, Mesa State College, August 29, 1997, "Connecting the KdV and NLS Hierarchies in the Zero Dispersion Limit".

J.F. Clarke, College of Aeronautics, Cranfield University, England, September 12, 1997, "Modeling Internal Ballistics".

Scott Parker, Department of Physics, University of Colorado, Boulder, September 26, 1997, "Large-scale Gyrokinetic Simulation of Tokamak Plasma Turbulence".

James H. Curry, Department of Applied Mathematics, University of Colorado at Boulder, October 3, 1997, "Root finding methods and Dynamical Systems: Some Non-invertible Mappings of the Plane Based on Newton's Method".

Robert Ecke, Center for Nonlinear Studies, Los Alamos National Laboratory, October 10, 1997, "Nonlinear Traveling Waves in Rotating Rayleigh-Benard Convection".

Patrick Weidman, Department of Mechanical Engineering, University of Colorado, Boulder, October 17, 1997, "The Faraday Experiment on a Soap Film".

Christopher Jordan, Department of EPO Biology, University of Colorado at Boulder, October 24, 1997, "The Mechanics of Undulatory Swimming: Lessons from Virtual and Robotic Leeches".

Nicholas Coult, Department of Applied Mathematics, University of Colorado at Boulder, October 31, 1997, "Numerical Homogenization of Partial Differential Equations".

Douglas Nychka, Geophysical Statistics Project, National Center for Atmospheric Research & Department of Statistics, North Carolina State University, November 14, 1997, "Interpolating Surfaces, Space-filling Designs and Monitoring Ozone Pollution".

Alan Hastings, Division of Environmental Studies, University of California, Davis, November 21, 1997, "Nonlinear Dynamics in Ecology".

Jerrold Bebernes, Department of Applied Mathematics, University of Colorado at Boulder, December 5, 1997, "Shear Banding--A Study in Nonlocal Problems".

H.S. Dumas, Math Department, University of Cincinnati, January 16, 1998, "Filling Rates for KAM-like flow on the Torus, with Applications".

Mary Silber, Department of Applied Mathematics, Northwestern University, January 23, 1998, "Spontaneous Symmetry-Breaking and Superlattice Wave Patterns".

Leonid Bunimovich, Department of Mathematics, Georgia Institute of Technology, January 30, 1998, "Dynamics of Production Lines in Work-sharing Industries".

Brian Hunt, Department of Mathematics, University of Maryland, February 27, 1998, "Riddled and Intermingled Basins".

Steven Pruess, Department of Mathematical and Computer Sciences, Colorado School of Mines, March 6, 1998, "Sledge, a Software Package for the Numerical Solution of Sturm-Liouville Problems".

Christoph Pflaum, Universität Würzburg, Institut für Angewändte Mathematik und Statistik, March 13, 1998, "Robust Multilevel Algorithms for Elliptic Differential Equations".

Gene Allgower, Department of Mathematics, Colorado State University, March 20, 1998, "Exploiting Symmetry in Numerical Analysis".

Mark Ablowitz, Department of Applied Mathematics, University of Colorado at Boulder, April 3, 1998, "Solitons: From Water Waves to Communications and Encryption".

A.S. Fokas, Department of Mathematics, Imperial college, London, April 17, 1998, "Integrability: From D'Alembert to Lax".

Paul Milewski, University of Wisconsin, Madison, April 24, 1998, "Effects of a Varying Bottom on Nonlinear Surface Waves".

Alan Bishop, Center for Nonlinear Studies, Los Alamos National Laboratory, May 1, 1998, "Complex Matter: Multiscale Phenomena in Hard and Soft Materials".

6. Seminars in Applied Mathematics, 1997-98

The Department maintained the Applied Mathematics Seminar, a weekly seminar series on Thursday afternoons at 4:00 p.m. Each Thursday, we used the Physics seminar room G-031 and had coffee and tea on the 11th floor of Duane Physics. We are grateful to the Physics department for allowing us to use their facilities. A list of visiting speakers and the titles of their talks follows:

N. Swaminathan, Department of Mechanical and Mechatronic Engineering, The University of Sydney, New South Wales, Australia, September 4, 1997, "Interdependence of the Instantaneous Flame Front Structure and the Overall Scalar Flux in Turbulent Premixed Flames".

Stephen Lekson, University Museum, University of Colorado at Boulder, September 25, 1997, "Emergent Order and the Archaeology of Government".

Wendy Welsh, National Center for Atmospheric Research, Boulder, CO, October 2, 1997, "Root Finding Methods and Dynamical Systems: Some Non-invertable Mappings of the Plane Based on Newton's Method".

Harvey Segur, Department of Applied Mathematics, University of Colorado at Boulder, October 9, 1997, "The Motion of a Falling Liquid Filament".

Sylvana Delillo, Universitá di Perugia, Italy, October 16, 1997, "The Burgers Equation With Moving Boundary".

Hector Lomeli, Department of Applied Mathematics, University of Colorado at Boulder, November 13, 1997, "Quadratic Volume Preserving Maps".

Lev Ostrovsky, Cooperative Institute for Research in Environmental Sciences, University of Colorado/NOAA Environmental Technology Laboratory, Boulder, CO, November 20, 1997, "Asymptotic Perturbation Theory in Vortex Dynamics".

Ben Herbst, Department of Applied Mathematics, University of Stellenbosch, January 22, 1998, "On an Automated Signature Verification System".

Leonid Bunimovich, Department of Mathematics, Georgia Institute of Technology, January 29, 1998, "Space-time Chaos in Nonlinear Wave Equations".

K.A. Naugolnykh, Cooperative Institute for Research in Environmental Sciences, University of Colorado/NOAA, Environmental Technology Laboratory, February 5, 1998, "Nonlinear Propagation of Laser-generated Sound Pulses in Water and Granular Media".

Robert Carlson, University of Colorado at Colorado Springs, February 19, 1998, "Hill's Equation for a Regular Graph".

Miki Wadati, Department of Physics, University of Tokyo, Japan, February 26, 1998, "Collapse of the Bose-Einstein Condensate Under a Magnetic Trap".

John Westman, University of Chicago, Illinois, March 5, 1998, "Nonlinear Stochastic Optimal Control Using Least Squares LQGP Approximation".

Mark Rast, High Altitude Observatory, NCAR, March 12, 1998, "Simultaneous Solution Of the Navier-Stokes and Elastic Membrane Equations".

Ute Herzfeld, Institute of Arctic and Alpine Research, University of Colorado at Boulder And Geomathematik Universität Trier, Germany, March 19, 1998, "Analysis and Simulation of Non-self-similar Fractal Processes, with Application to Marine Geology".

Fred Glover, Media One School of Business, University of Colorado at Boulder, April 2, 1998, "New Advances in Optimization—Combining Evolutionary Procedures, Neural Networks and Tabu Search".

James Meiss, Department of Applied Mathematics, University of Colorado at Boulder, April 2, 1998, "Symbolic Dynamics and the Breakdown of the Horseshoe".

Dave Meyer, Department of Electrical Engineering, University of Colorado at Boulder, April 2, 1998, "Dynamically Path-planning the Consolidation of Titanium Matrix Composite Materials".

Thomas Peacock, Center for Environmental Research in the Sciences, University of Colorado at Boulder, April 9, 1998, "Bifurcation Phenomena in Flows of a Liquid Crystal".

A.S. Fokas, Department of Mathematics, Imperial College, London, April 16, 1998, "Some Recent Applications of Painléve Equations: (a) A Hele-Shaw type Problem, (b) Stimulated Raman Scattering".

Jeff Luftig, President of Luftig and Warren International, May 7, 1998, "Statistical Tales from the Front".

F. Treves, Rutgers University, New Brunswick, NJ, May 14, 1998, "Parametrices For a Class of Time-dependent Schrödinger Equations".

C. University of Colorado, Denver - University of Colorado, Boulder Joint Seminars in Computational Mathematics, 1997-98

The Joint CU Denver-CU Boulder Computational Math Seminar continued the expanded form of last year, with the regular lecture on Tuesdays at 12:00 preceded by three hours of open discussion, with the location alternating between Denver and Boulder. There were typically 20 or more faculty, students, and visitors from the two campuses attending the open discussions and regular lectures. A list of speakers and the titles of their talks follows:

Tom Manteuffel, Department of Applied Mathematics, University of Colorado at Boulder, September 2, 1997, "Adaptive Refinement and Singular Functions with First-Order Systems Least Squares Functionals," (on Boulder Campus).

Martin Stynes, University College Cork, Ireland, September 16, 1997, "OptimalApproximability of Solutions of Singularly Perturbed Differential Equations," (on Denver Campus).

Rich Le Houcq, Sandia National Laboratory, Albuquerque, NM, October 7, 1997, "The Numerical Solution of the Large Scale Eigenvalue Problem with Orthogonal Projection Methods," (on Boulder Campus).

Andrew Knyazev, University of Colorado at Denver, October 21, 1997, "NumericalSolution of elliptic Problems with Highly   Discontinuous Coefficients," (on Denver Campus).

Van Emden Henson, Lawrence Livermore National Lab, November 4, 1997, "AMG Rules! Or: How I Learned to Stop Geometric Gridding and Love the Matrix," (on Boulder Campus).

Leopoldo P. Franca, University of Colorado at Denver, November 18, 1997, "Approximation of the Advective-Diffusive and Helmholtz Equations Based on a Two-Level Finite Element Method," (on Boulder Campus).

Bill Spotz, NCAR, December 2, 1997, "Towards Faster Global Climate Models," (on Boulder Campus).

Marian Brezina, Department of Applied Mathematics, University of Colorado at Boulder, January 27, 1998, "A General Framework for Multilevel Methods that Includes both Multigrid and Domain Decomposition," (on Boulder Campus).

Bill Briggs, University of Colorado at Denver, February 17, 1998, "Population Genetics Models," (on Denver Campus).

Christoph Pflaum, University of Würzburg, Germany, April 7, 1998, "Nitsche Trick for FOSLS," (on Boulder Campus).

John Trapp, UCD Mechanical Engineering, April 21, 1998, "Local Numerical Modeling of Two-Phase Flows with Phase Changes," (Progress and Problems), (on Boulder Campus).

Daniel J. Quinlan and Bill Henshaw, Scientific Computing Group, Los Alamos National Laboratory, May 5, 1998, "An Object-Oriented Framework for Solving PDEs on Structured Grids," (on Denver Campus).

D. Other Seminars, 1997-98

Dynamical Systems Seminars:

The weekly Dynamical Systems seminar is a research working group led by James Meiss and Robert Easton, who each spoke at the Seminar. In the fall, the group studied a number of research papers in topics such as ecological modeling, Arnold diffusion, and non-invertible maps. In the fall, we hosted Scott Dumas, from the University of Cincinnati, Mary Silber, Northwestern University, and Leonid Bunimovich, of the Georgia Institute of Technology. In the spring, we hosted several visitors, including Bob Devaney of Boston University, Brian Hunt from the University of Maryland, and Dick Kautz, of NIST.

The following Seminars were sponsored by the SIAM undergraduate chapter:

SIAM Undergraduate Seminars:

Professor James H. Curry, Department of Applied Mathematics, University of Colorado at Boulder, October 2, 1997, Applied Math Majors Meeting.

Amanda Tarr and Kai Tagawa of VR-1, October 22, 1997, "Computer Graphics and Linear Algebra".

Professor Bengt Fornberg, Department of Applied Mathematics, University of Colorado at Boulder, January 26, 1998, "Resume Writing Workshop".

Other Chapter activities included hosting several mentor lunches to promote interactions among the undergraduate applied math majors and the faculty.

7. COMMITTEES

A. Undergraduate Committee

The members of the Undergraduate Committee were Jerry Bebernes, Jim Curry (ex officio), and Bob Easton (Chair). Anne Dougherty was Faculty Advisor to SIAM, an undergraduate Applied Math organization.

The Department in Applied Mathematics had 44 undergraduate majors this year. During the academic year 25 of our majors were on the Dean's list with a grade point average of 3.5 or better during either the fall or spring semester. Carolyn Jean Noonan won the 1998 Henrie-James Award as the outstanding applied mathematics major who is going on to graduate school. Fifteen students graduated this year with bachelor of science degrees in applied mathematics. Five of these students graduated with a cumulative grade point average of 3.5 or better. Six majors graduated with at least a minor in another field and five others graduated with double majors. Finally, two of our students graduated with distinction (GPA of 3.8 or better) or high distinction (GPA of 3.9 or better).

The minor in Applied Mathematics, available to students in the College of Arts and Sciences or in Engineering, is growing. There are now 23 students who are pursuing a minor in Applied Mathematics or who have graduated with the minor during the past year.

The undergraduate student chapter of SIAM (the Society for Industrial and Applied Mathematics) continues to be very active. There are over twenty members in the chapter. Events this past year included meetings, technical presentations by invited speakers, and mentor lunches. Joe Pearse continued as President, Mike Rempe was Vice President, Emily Hagn was Secretary/Treasurer and Ann Windnagel was UCEC Representative. Joe Pearse pursued and secured a grant from the Engineering Undergraduate Excellence Fund, in order that the department's undergrad students would have available three Silicon Graphics 02 computers. This has been a significant success for Applied Math. For the 1998-99 academic year, Leda Schwartz will be President, and Mike Rempe Vice President.

The Department in Applied Mathematics, with assistance from the undergraduate SIAM chapter, entered two 3-person teams in the 1998 Mathematical Contest in Modeling. This international exam, sponsored by COMAP (The Consortium for Mathematics and its Applications), ran from 12:01 a.m. February 6, until 5:00 p.m. February 9, and drew 472 entries from around the world.

Team 1: Gregg Bachmeyer, Brent Bachmeyer and Chris Falvey, with faculty advisor Anne Dougherty, was designated as Meritorious (in the top 15% of competing teams).

Team 2: Erik Jasiak, Carolyn Noonan and Joe Pearse, with faculty advisor Bengt Fornberg, was designated as Successful Participant.

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B.   Graduate Committee – Bengt Fornberg, Chair

The graduate committee for 1997-98 consisted of Bengt Fornberg (Chair), Congming Li, Tom Manteuffel and Harvey Segur.

The main business of the committee is to advise the current graduate students, process graduate applications, decide on admission to the graduate program and administer the preliminary exams. These exams are given twice each year, in four areas: Applied Analysis, Computational Analysis, Partial Differential Equations and Probability/Statistics.

The program had 51 graduate students during 1997-98, of whom 14 began in the fall of 1997 and one in the spring of 1998. During the year, three students received PhDs and eleven received MS degrees. For the fall semester of 1998, there were 40 applicants, of whom eight were awarded teaching assistantships.

The number of funded teaching assistantships has remained at about 17-19 for the past seven years. Now a majority of our graduate students are supported on research contracts. The percentage of American students has fluctuated between 80-90%, while the percentage of women students fluctuated between 21-41%. For minority students, the recent percentage range has been 6-15%.

Just at the end of the 1997-98 academic year, NSF notified the Department that we will receive an NSF VIGRE grant for the next five years, with support of graduate students and Postdocs, totaling $2.34 million. This funding will start in late spring 1999 – about at the same time as when our earlier (and much smaller) NSF Traineeship grant finishes. We expect that our graduate program will continue a slow growth in size – maybe towards 65 students – and that we will become even better positioned to attract the very best graduate candidates.

In summary, the graduate program of the Department has come of age. While we have improvements to make, we believe it has developed remarkably well during its soon ten years of existence, and that it is continuing to enhance its ability to produce highly qualified and marketable applied mathematicians.

6. FACULTY SERVICE TO THE UNIVERSITY, DEPARTMENT AND SOCIETIES, CALENDAR YEAR 1997

Mark Ablowitz: Department Chair; Member of Council of Chairs in the College of Arts and Sciences; and American Mathematical Society Short Course Committee

Jerrold Bebernes: Member of Department Personnel Committee; Member of Department Undergraduate Committee, Fall 1997

Gregory Beylkin: Member of Department Graduate Committee, and NSF-DARPA OPAL Panel; Consulted for Fast Mathematical Algorithms and Hardware, Corp.; Consulted for Amoco; Sabbatical 1997-98

James Curry: Department Associate Chair; CO-PI Connect Colorado Statewide Systemic Initiative; Member of Advisory Board for the NSF Geometry Center, Campus Committee for Information Technology, Presidential Teaching Scholar Selection Committee, and Vice Chancellor Search Committee

Anne Dougherty: Member Probability and Statistics Preliminary Committee, Department of Applied Math; Faculty Advisor for 1997 Math Modeling Contest; First-Round Judge for the (National) 3rd Annual Undergraduate Data Analysis Contest; Faculty Participant in both the Engineering Open House activities and the Women in Engineering Career Days Program, 1997; Faculty Advisor for the SIAM, (Society for Industrial and Applied Mathematics) undergraduate chapter

Robert Easton: Chair, Undergraduate Committee; Chair, Department Diversity Committee; Transfer Credit Evaluator; Member College Educational Policy and Planning Committee, College of Engineering; Member of Center for Chaos and Complexity; Participant of College of Engineering High School Honors Institute; Sabbatical, Fall-97; Member Undergraduate Academic Affairs Committee, College of Engineering

Bengt Fornberg: Visiting Professor of Mathematics, University of Strathclyde, Scotland (1991-1997); Chairman, Graduate Committee and member of the Budget Committee, Department of Applied Mathematics; Member of the University Council on Research and Creative Work; Consultant to Division of Applied Mathematics, Brown University, on Air Force project in Computational Electromagnetics; Major Revision of Existing Course: Extensive introduction of Mathematica into Graduate Asymptotics/Perturbation methods class (APPM 5480)

Keith Julien: Assistant Professor of Applied Mathematics; Member of the Peer Review Panel for NASA 1998 Grant Proposals, November, 1997; Reviewer for six Grant Proposals to Sun-Earth Connection Program, November 1997

Congming Li: Member of Department Graduate Committee

Hector Lomeli: Member of Boulder Campus Early Alert Program Committee

Tom Manteuffel: Society of Industrial and Applied Mathematics: Vice-President, Chair of Science Policy Committee, Member Master Program Committee, Chair of Major Awards Committee; Consultant, Lawrence Livermore National Laboratory; Graduate Committee, Department of Applied Mathematics: Graduate committee, Computing Committee, Compensation Committee; Arts and Science Council, ASC Grievance Committee (Spring 1998), ASC Planning Committee (Fall 1997); Co-Chair: Copper Mountain Conference on Multigrid Methods, Copper Mountain, CO., March 30-April 3, 1998

Steve McCormick: Consultant, Lawrence Livermore National Laboratory; Department of Applied Mathematics, Graduate Committee Chairman, Computing Committee; Co-Chair, Copper Mountain Conference on Multigrid Methods, Copper Mountain, March 30-April 3, 1998

James Meiss: Member of Department Undergraduate Committee, Department Graduate Committee, Department Computer Committee, Center for Integrate Plasma Studies, Colorado Center for Chaos and Complexity, and University Scholarship Committee; Campus Representative for the Goldwater Scholarship

Harvey Segur: Member of Department Graduate Committee, Boulder Faculty Assembly, University Faculty Council; Sabbatical 1996-97

John Williamson: Chair, Undergraduate Committee, Jan. 1 to July 1, 1997; Member of Undergraduate Committee, Jan. 1 to December 31, 1997; College of Engineering, Scholarship Committee, Jan. 1 to Dec. 31, 1997; College of Engineering, Undergraduate Academic Affairs Committee, Jan. 1 to July 1, 1997; Engineering Planning and Policy Committee, Jan. 1 to July 1, 1997; Member of Executive Committee for the Certificate Program in Actuarial Studies, July 1 to Dec. 31, 1997; Coordinator for Statistics Coordinating Committee

7. TEACHING ACTIVITIES

A. Courses Taught by Department Faculty, Academic Year 1997-98

(I) Undergraduate Courses

APPM 1350   *Dougherty, Easton, Li, Lomeli, Norris,* Calculus 1 for Engineers.

APPM 1360   *Biondini, Herod, Halburd, Lomeli, Segur,* Calculus 2 for Engineers.

APPM 2350   *Herod, Li, Manteuffel,* Calculus 3 for Engineers.

APPM 2360   Bebernes, *Halburd, Julien, Meiss,* Linear Algebra and Diff. Equations.

APPM 2460   *Carter,* Differential Equations Lab.

APPM 3010   *Lomeli,* An Introduction to Nonlinear Systems: Chaos.

APPM 3310   *Curry, Easton,* Matrix Methods and Applications.

APPM 3570   *Williamson,* Applied Probability.

APPM 4350   *Segur,* Methods in Applied Mathematics 1: Boundary Value Problems.

APPM 4360   *Ablowitz,* Methods in Applied Mathematics 2: Complex Variables.

APPM 4380   *Fornberg,* Modeling in Applied Mathematics.

APPM 4520   *Williamson,* Introduction to Mathematical Statistics.

APPM 4560   *Williamson,* Introduction to Probability Models.

APPM 4570   *Dougherty,* Statistical Methods.

APPM 4580   *Dougherty,* Statistical Methods Data.

APPM 4650   *Easton,* Introduction to Numerical Analysis.

APPM 4660   *Driscoll,* Intermediate Numerical Analysis 2.

APPM 4955   *Curry,* Seminar--Applied Mathematics.

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(II) Graduate Courses

APPM 5350	*Segur,*	Methods in Applied Mathematics: Boundary Value Problems.
APPM 5440	*Bebernes,*	Applied Analysis 1.
APPM 5450	*Bebernes,*	Applied Analysis 2.
APPM 5470	*Meiss,*	Methods in Applied Mathematics 3: Partial Differential Equations.
APPM 5560	*Williamson,*	Introduction to Probability Problems.
APPM 5570	*Dougherty,*	Statistical Methods.
APPM 5600	*Fornberg,*	Numerical Analysis 1.
APPM 5610	*Fornberg,*	Numerical Analysis 2.
APPM 6550	*Williamson,*	Introduction to Stochastic Processes.
APPM 7300	*Segur,*	Nonlinear Waves.
APPM 7400	*Ablowitz,*	Complex Variables.
APPM 7400	*Curry,*	Seminar—Teaching and Learning.
APPM 7400	*Meiss,*	Dynamical Systems, Special Topics.
APPM 8000	*Meiss,*	Colloquium.
APPM 8100	*Ablowitz,*	Seminar--Nonlinear Equations.
APPM 8100	*Meiss,*	Seminar--Dynamical Systems.
APPM 8200	*Manteuffel,*	Seminar--Computational Mathematics.

B. Summer Courses, 1998

APPM 1350	*Tenfjord,*	Calculus 1 For Engineers.
APPM 1360	*Cotae, Nelson ,*	Calculus 2 for Engineers.
APPM 2350	*Robins,*	Calculus 3 for Engineers.
APPM 2360	*Akmaev,*	Introduction to Linear Algebra and Differential Equations.
APPM 2450	*Wright,*	Calculus 3 Lab.
APPM 2460	*Edgin,*	Differential Equations Lab.
APPM 4650	*Norris,*	Intermediate Numerical Analysis 1.

8. RESEARCH ACTIVITIES FOR CALENDAR YEAR 1997

A. Research Publications for Calendar Year 1997

Mark Ablowitz:

"Complex Variables: Introduction and Applications," Mark J. Ablowitz and A.S. Fokas, *Cambridge University Press*, Cambridge, UK, 1997, 647 pages.

"Solutions to the Time Dependent Schrödinger and the Kadomtsev-Petviashvili Equations,"M.J. Ablowitz and J. Villarroel, *Phys. Rev. Letters*, **78** (1997) 570-573.

"The Nonlinear Schrödinger Equation: Asymmetric Perturbations, Traveling waves and Chaotic Structures," M.J. Ablowitz, B.M. Herbst and C.M. Schober, *Mathematics and Computers in Simulation*, **43** (1997) 3-12.

"Initial Time Layers and Kadomtsev-Petviashvili Type Equations," M.J. Ablowitz and X-P Wang, *Stud. Applied Mathematics* , **98** (1997) 121-137.

"On the Well-Posedness of the Eckhaus Equation," M.J. Ablowitz, G. Biondini and S. De Lillo, *Phys Letters* A, **230** (1997) 319-323.

"On the Numerical Solution of the Sine-Gordon Equation II. Performance of Numerical Schemes," M.J. Ablowitz, B.M. Herbst and C.M. Schober, *Journal of Comp. Physics*, **131** (1997) 354-367.

"Four-wave Mixing in Wavelength-division Multiplexed Soliton Systems—Ideal Case," M.J. Ablowitz, G. Biondini, S. Chakravarty, R.B. Jenkins and J.R. Sauer, *Journal of the Optical Society of America B*. **14** (1997) 1788-1794.

"Multi-dimensional Pulse Propagation in Non-resonant Chi (2) Materials," M.J. Ablowitz, G. Biondini and S. Blair, *Physics Letters A*, **236** (1997) 520-524.

"Painlevé Test" and "Painlevé Type Equations," in *Encyclopedia of Mathematics Supplement*, Volume I, Editor-in-Chief, Professor M. Hazewinkel, Kluwer Academic Publishing, (1997), 397.

Jerrold Bebernes

"Travelling Fronts in Cylinders and their Stability," (with C. Li and Y. Li), *Rocky Mountain Journal of Mathematics*, **27** (1997), 1-27.

"Global existence and Finite-time Blow-up of Nonlocal Parabolic Problems," (with A. Lacey), *Advances in Differential Equations*, **2** (1997), 927-954.

"Nonlocal Problems Modelling the Formation of Shear Bands," *Proceeding of Eighth International Colloquium on Differential Equations*," D. Bainov, Editor, VSP, Utrecht, Netherlands, (1997).

"Shear Banding—A Study in Nonlocal Problems," *Proceedings of Conference in Honor of Retirement of Gary Meisters*, University of Nebraska, (1997).

Gregory Beylkin:

"On the Adaptive Numerical Solution of Nonlinear Partial Differential Equations in Wavelet Bases," (with James Keiser), *Journal of Computational Physics*, **132** (1997) 233-259.

"An Adaptive Pseudo-Wavelet Approach for Solving Nonlinear Partial Differential Equations," (with James Keiser), Chapter in *Multiscale Wavelet Methods for Partial Differential Equations*, 6, in the Wavelet Analysis and Applications series, Academic Press, (1997).

James H. Curry:

"Lyapunov Exponents, Singularities, and a Riddling Bifurcation," *Physical Review Letters,* **79, #6.**

Ann Dougherty:

"Book Review of Engineering Statistics: The Industrial Experience," in *The American Statistician,* (1997).

"Extreme Wind Estimation; Theoretical Considerations," *Proceedings of the 7th International Conference on Structural Safety and Reliability,* A. Dougherty and R. Corotis, (1997).

Holger Dullin:

"Symbolic dynamics and Periodic Orbits for the Cardioid billiard," with A. Becker, J. Phys. A, 30 (1997) pp. 1991-2020.

"On the Euler Case in Rigid Body Dynamics and the Jacobi Problem," with A.V. Bolsinov, Regular and Chaotic Dynamics, 2 (1997) pp. 13-25.

"Elliptic Quantum Billiard", with H. Waalkens and J. Wiersig, Ann. Physics 260 (1997).

"The Kovalveskaya Top," with P.H. Richter and A. Wittek, Film C 1961, Publikationen zu Wissenschaftlichen Filmen 13 (1997).

Bob Easton:

"Geometric Methods for Discrete Dynamical Systems," *Oxford University Press,* **50,** (1998).

Bengt Fornberg:

"A High-order Finite Difference Method applied to large Rayleigh Number Mantle Convection," T.B. Larsen, D.A. Yuen, J. Moser and B. Fornberg, *Geophysics, Astrophysics and Fluid Dynamics,* **84** (1997) 31 pp.

"Comparison of Finite Difference and Pseudospectral Methods for Convective Flow over a Sphere," B. Fornberg and D. Merrill, *Geophysical Research Letters* **24** (1997), 4pp.

"Pseudospectral Methods for Large-scale Bioacoustic Models," G. Wojcik, B. Fornberg, R. Waag, L. Carcione, J. Mould, L. Nikodym and T. Driscoll, *IEEE Ultrasonics Symposium Proceedings* (1997), 6 pp.

Keith Julien:

"Fully Nonlinear Oscillatory Convection in a Rotating Layer," K. Julien and E. Knoblock, *Phys.. Fluids* **9,** (1997), p.1906.

"Plume Dynamics in Quasi Two-Dimensional Turbulent Convection," C.A. Bizon, A. Predtechensky, J. Werne, K. Julien, W.D. McCormick, J.B. Swift and H.L. Swinney, *Chaos* **7** (1997), p.1.

"Dynamics and Scalings in Quasi Two-Dimensional Turbulent Convection," C..A. Bizon, J. Werne, A. Predtechensky, K. Julien, W.D. McCormick, J.B. Swift, and H.L.Swinney, *Physica A* **239** (1997), p. 204.

"The Effect of Rotation on the Global Dynamics of Convection," K. Julien, J. Werne, S. Legg and J. McWilliams, Solar Convection and Oscillations and their Relationships Conference, *Kluwer Academic Publishers,* (1997), p. 231.

"The Effect of Rotation on Convective Overshoot," K. Julien, J. Werne, S. Legg, and J. McWilliams, Solar Convection and Oscillations and their Relationships Conference, *Kluwer Academic Publishers,* (1997), p. 227.

Congming Li:

"A Priori Estimates for Prescribing Scalar Curvature Equations," *Analytical Mathematics*, **145**, (1997) 547-564.

"Indefinite Elliptic Problems in a Domain", *Discontinued and Continued Dynamics Systems*, **3** (1997) 333-340.

"Travelling Fronts in Cylinders and their Stability," *Rocky, Mountain Journal of Mathematics*, **27** (1997) 123-150.

Hector Lomeli:

"Quadratic Volume Preserving Maps: a Normal Form," H.E. Lomeli and J.D. Meiss, *Nonlinearity*, (1997).

Tom Manteuffel:

"First-Order System Least Squares for Second-Order Partial Differential Equations: Part II," with Z. Cai and S. McCormick, *SIAM J. Numerical Analysis*, **34**, No. 2, (1997).

"First-Order System Least Squares for Stokes Equations, with Application to Linear Elasticity," with Z. Cai and S. McCormick, *SIAM Journal of Numerical Analysis*, **34**, (1997) 1727-1741.

Steve McCormick:

"First-order System Least Squares for Second-Order Partial Differential Equations: Part II," with Z. Cai, and T.A. Manteuffel, *SIAM J. Numerical Analysis*, *34*, (1997) pp. 425-454.

"First-Order System Least Squares for Stokes Equations, with Application to Linear Elasticity," with Z. Cai, and T.A. Manteuffel, *SIAM Journal of Numerical Analysis*, **34**, (1997) 1727-1741.

"Control-Volume Mixed Finite Element Methods," with Z. Cai, J. Jones and T. Russell, *Computational Geosciences*, **1**, (1997), 289-315.

"Multigrid Methods for Nearly singular Linear Equations and Eigenvalue Problems," with Z. Cai and J. Mandel, *SIAM J. of Numerical Analysis*, **34**, (1997)178-200.

"Parallel Multigrid Methods," NASA/LaRC Interdisciplinary Series in Science and Engineering, Parallel Numerical Algorithms , Kluwer (1997).

James Meiss:

"Average Exit Time for Volume Preserving Maps," J.D. Meiss, *Chaos* , **7**, (1997) 139-147.

"Quadratic Volume Preserving Maps: a Normal Form," H.E. Lomeli and J.D. Meiss, *Nonlinearity*, (1997)."Computing Periodic Orbits using the Anti-Integrable Limit," D. Sterling and J.D.Meiss, *Physics Letters A,* (1997).

Harvey Segur:

"The KP Equation with Quasiperiodic Initial Data," with Bernard Deconinck, *Physica D*."A Discrete Curve-Shortening Equation," with N.K. Nakayama and M. Wadati, *Methods and Applications of Analysis*, 4, (1997), 162-172.

"Three-Phase Solutions of the Kadomtsev-Petviashvili Equation," with F.A. Dubrovin and R. Flickinger," *Studies in Applied Math*, **99**, (1997), 137-203.

"Motion of Curves Specified By Accelerations," with T. Tsurumi K. Nakayama, and M.Wadati, *Physics Letters A* **224**, (1997), 253-263.

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B. Invited Lectures and Meetings Attended for Calendar Year 1997

Mark Ablowitz:

Conference on Soliton Theory, PDE's and Nonlinear Analysis, University of New South Wales, Sydney, Australia, "On Solutions of the Nonstationary Schrödinger and Kadomtsev-Petviashvili Equations," Jan 6-9, 1997.

Conference on Chaos and Integrability in Discrete Systems, International Solvay Institutes for Physics and Chemistry, Vrije University, Brussels, Brussels, Belgium, "Computational and Effective Chaos in Integrable Systems," July 1997.

AFOSR Workshop on Nonlinear Optics, Tucson, Arizona, "Wavelength Division Multiplexed (WDM) Solutions: Collision Induced Timing Jitter," September 24, 1997.

Jerrold Bebernes

Mathematics Department, Colorado State University, "Nonlocal Parabolic Problems," Colloquium Talk, April 3, 1997.

SIAM Conference on Mathematics in the Geosciences, Albuquerque, N.M., "Modelling of Shear Band Formation" Invited Talk, June 18, 1997.

Department of Applied Math, University of Colorado at Boulder, "Nonlocal Problems Arising in Shear Banding," Colloquium Talk, December 5, 1997.

Gregory Beylkin:

Oak Ridge National Laboratories, "Multiresolution Regularization of Singular Operators and Fast Summation Algorithms," January 17, 1997.

Space Warfare Center, "Efficient Representation of the Earth's Gravitational Field," February 28, 1997.

University of Texas, "Efficient Representation of the Earth's Gravitational Field," May 23, 1997.

DARPA, "A Multiresolution Approach to SAR Processing", April 23, 1997.

DARPA, "Applications of Unequally Spaced Fast Fourier Transform," April 24, 1997.

DARPA/Hughes, "Fast Multiresolution Algorithms," June 9, 1997.

Conference Alex Grossman, Luminy, France, "A New Class of Stable Time Discretization Schemes for the Solution of Nonlinear PDEs," July 1997.

Summer School at Luminy, France, "Multiresolution Strategy for Homogenization," July 1997.

Mittag-Leffler Institute, Sweden, "A New Class of Stable Time Discretization Schemes for the Solution of Nonlinear PDEs," September 1997.

Lund University, Sweden, "Multiresolution Strategy for Reduction and Homogenization," October 1, 1997.

Stanford University, "An Adaptive Pseudo-wavelet Approach to Solving Nonlinear PDEs," October 24, 1997.

Invited Lecture, AMS Western Section, "An Adaptive Pseudo-Wavelet Approach to Solving Nonlinear PDEs," November 8, 1997.

James H. Curry:

Presented Manuscript at Lawrence Berkeley Laboratory Conference, "Singularities in Dynamical Systems," March 1997.

Invited Lecture, CAARMS4 Conference, "Relaxing Chaos: A Study of Newton's Method," June 16, 1997.

Anne Dougherty:

Invited Participant, NSF Sponsored Workshop on Mathematical Techniques to Mine Massive Data Sets, November 1997.

Bob Easton:

University of Colorado, Department of Applied Math, Several Lectures on the Levitron, Applied Math Dynamical Systems Seminar, Fall semester, 1997.

Invited Talk, "Dynamics of the Levitron," University of Wisconsin Department of Mathematics Conference in Celebration of the Centennial of the first PhD in Mathematics awarded at the University, May 1997.

Invited Talk, "Dynamics of a Levitating Magnetic Top," SIAM Conference on the Applications of Dynamical Systems, Snowbird, Utah, May 1997.

Bengt Fornberg:

Invited Talk, presented at 17th Biennial Conference on Numerical Analysis, University of Dundee, Scotland. "The Pseudospectral Element Method for One-dimensional Hyperbolic systems," June 1997.

Colloquium Speaker, Wichita State University, University of Wyoming, Uppsala University (Sweden; two different colloquia) University of Strathclyde (Scotland), University of Cape town and Stellenbosch University (both South Africa-two different colloquia at each), July 1997.

Keith Julien:

Colloquium Speaker, Colorado State University, "A New Class of Equations for Rotationally Constrained Flows," April 1997.

Congming Li:

Invited Talk, The First Tianyuan Conference of Mathematical Sciences, Berkeley, CA, 6/28-7/2, 1997.

Seminar, University of California, Los Angeles, Department of Mathematics, June 26, 1997.

Hector Lomeli:

Invited Speaker, University of Minneapolis, MN, Midwestern Dynamical Systems Conference, "Quadratic Volume-Preserving Maps, September 1997.

Tom Manteuffel:

Guest Speaker, Copper Mountain, CO, Copper Mountain Conference on Multigrid Methods, April 7-11, 1997.

Invited Speaker, Oberwolfach, Germany Workshop on Numerical Linear Algebra, April 14-18, 1997.

Invited Speaker, Jackson Hole, WY, IMACS Conference on Numerical Methods for PDEs, July 10, 1997.

Invited Speaker, SIAM Annual Meeting, Mini-symposium of Least-Squares Finite Element Methods July 17, 1997.

Colloquium Speaker, North Carolina State University, Raleigh, NC, November 14, 1997.

Steve McCormick:

Speaker, Copper Mountain, CO, Copper Mountain Conference on Multigrid Methods, April 7-11, 1997.

Invited Speaker, Jackson Hole, WY, IMACS Conference on Numerical Methods for PDEs, July 10, 1997.

James Meiss:

Colloquium for Colorado State University, Fort Collins, "Chaotic Trajectories to the Moon," March 8, 1997.

Invited Speaker, SIAM Dynamical Systems conference, Snowbird, Utah, "Quadratic Volume Preserving Maps: a Normal Form," May 18-22, 1997.

Invited Speaker, Southwest Dynamical Systems Meeting, Denton, Texas, "Transit Time Decompositions for Area Preserving Maps," April 11-13, 1997.

Harvey Segur:

Invited Speaker, University of Tokyo, Tokyo, Japan, "Waves in Shallow Water," January 24, 1997.

Invited Speaker, University of Kyoto, Kyoto, Japan, RIMS Conference, "Waves in Shallow Water," February 10, 1997.

Invited Speaker, University of Science and Technology, Hong Kong, "What's New in Integrable Problems?", March 12, 1997.

Invited Speaker, University of Science and Technology, Hong Kong, "Recent Results in Drop Formation," April 7, 1997.

Invited Speaker, Hong Kong Mathematical Society, Hong Kong Epson Lecture, "The KP Equation and Water Waves," April 11, 1997.

Invited Speaker, Los Alamos National Laboratory, Los Alamos, NM, CNLS Annual Meeting, "The KP Equation and Water Waves," May 12, 1997.

Seminar Speaker, University of Colorado at Boulder, Department of Applied Mathematics, "The Motion of a Falling Liquid filament," October 9, 1997.

John Williamson:

Invited Speaker for three lectures, based on published journal articles, given at the Institute of Behavioral Genetics as part of a course on "Quantitative Trait Loci,". Fall 1997.

C. Research Grants for Calendar Year 1997

	Amount for 1997
Mark Ablowitz:	
NSF, Mathematics Division: 1994-97	$74,300
AFOSR, Mathematics: 1997-99	$60,000
Air Force AASERT: 1993-97	$31,500
ONR AASERT: 1994-97	$35,900
Gregory Beylkin:	
DARPA: 1996-97	$52,100
NASA: 1996-99	$113,800
AFOSR: 1997	$130,200
James Curry:	
NSF Statewide Systemic Initiative: 1993-97	$25,000
Silicon Grail: 1997-98	$17,000
Bengt Fornberg:	
NSF, Mathematics Division 1997-2000	$13,500
Keith Julien:	
NASA, 1997-2000	$78,800
Congming Li:	
NSF, 1996-99	$22,900
Tom Manteuffel:	
DOE, Applied Mathematics: 1996-99	$50,000
NSF, Mathematics Division: 1994-97	$45,000
NSF, Mathematics Division: 1997-2000	$19,800
Steve McCormick:	
DOE: 1996-99	$50,000
NSF, Mathematics Division: 1994-97	$45,000
NSF, Mathematics Division:...1997-2000	$19,800
NSF, Special Projects: 1994-97	$11,400
James Meiss:	
NSF, Mathematics Division: 1996-99	$24,700
NSF, Graduate Traineeship: 1993-98	$111,000
Harvey Segur:	
NSF, Mathematics Division: 1993-97	$17,000
ONR, Physics/Oceanography Division: 1995-97	$23,200
John Williamson:	
NIMH: 1995-99	$48,200

D. Miscellaneous for Calendar Year 1997

Mark Ablowitz:

Editorial boards: *Journal of Engineering Mathematics; Studies in Applied Mathematics,*
  Cambridge University Press Texts in Applied Mathematics

Advisory boards: *Chaos, Inverse Problems*

Reviewer: NSF Grants; Air Force Grants; Australian and Canadian Research Grants;
  *Physics Letters A; Physical Review Letters; Studies in Applied Mathematics; SIAM
  Journal on Applied Mathematics; Journal of Engineering Math; Chaos, Inverse
  Problems, Cambridge University Press*

Jerrold Bebernes:

Editor: *Rocky Mountain Journal of Mathematics; Communications on Applied Nonlinear
  Analysis*

Gregory Beylkin:

Editorial boards: *SIAM Journal on Numerical Analysis;* Editorial and Advisory Board,
  Applied and Computational Harmonic Analysis

James Curry:

Refereed Journal Articles or Chapters: *SIAM Journal of Numerical Analysis* ; *Journal of
  the Atmospheric Sciences*

Robert Easton:

Editorial Board: *Communications on Applied Nonlinear Analysis;* Reviewed Proposals
  for the National science Foundation; Refereed Papers for several Mathematical Journals

Bengt Fornberg:

Visiting Professor: University of Strathclyde (1991-1997) Refereed about a dozen articles
  for six Journals; Proposal Evaluations for NSF and FRD (equivalent to NSF in
  Republic of South Africa)

Keith Julien:

Refereed a paper for: *Journal of Fluid Dynamical Research* in 1997, Refereed two papers
  for the *Journal of Fluid Dynamics* in 1997

Congming Li:

Reviewer: NSF proposals; *Rocky Mountain Journal of Mathematics; Communications in Pure and Applied Mathematics; Communications in Partial Differential Equations; Indiana University Mathematics Journal ; SIAM Journal of Mathematical Analysis*

Organizer: PDE session in International Conference on Dynamics and Differential Equations, Springfield, Missouri, SMSU, May-June 1996

Hector Lomeli:

Reviewer: *Physica D*

Tom Manteuffel:

Editor-in-Chief, SIAM Journal of Numerical Analysis Associate Editor, Journal of Numerical Linear Algebra and Applications

Steve McCormick:

Editor: SIAM Journal on Numerical Analysis

Editor: SIAM Journal on Scientific Computation

Sabbatical; CRCW Fellowship, 1997-98

James Meiss:

Editor: *Physica D*

Reviewer: *Physics Letters; Physical Review Letters; Journal of Fluid Mechanics; Journal of Physics A; Chaos; Physics of Plasmas; Physica D, Nature; Nonlinearity* , NSF Proposals

Harvey Segur:

Reviewer: Inverse Problems, Physica D, Physical Review E (2 Papers), Physical Review Letters, Physics Letters A (2 Papers), Proceedings of Royal Society of London, SIAM Journal on Applied Mathematics

9. PREPRINTS OF THE DEPARTMENT: 1997-98

Following is a list of preprints developed by Department faculty and visitors during this academic year. If you would like a copy of any preprint, please request a copy in writing from Lynn Randolph, Department of Applied Mathematics, Campus Box 526, University of Colorado, Boulder, CO 80309-0526.

Preprints for 1997-98

#338 *Symmetric Functions, Blowout Bifurcations, and On-off Intermittency*, by L. Billings, J.H. Curry and E. Phipps, August 1997.

#338R *Symmetric Functions and Exact Lyapunov Exponents*, by L. Billings, J.H. Curry, and E. Phipps, December 15, 1997.

#339 *The KP Equation with Quasiperiodic Initial Data*, by B. Deconinck and H. Segur, July 1997.

#340 *The Motion of a Falling Liquid Filament*, by H. Segur, November 1997.

#341 *Asymptotic Perturbation Theory in Vortex Dynamics*, by L. Ostrovsky, November 1997.

#342 *Collision-induced Timing Jitter in dispersion-managed Soliton Systems*, by M.J. Ablowitz, December 1997.

#343 *Soliton Communications and wavelength-division Multiplexing*, by M.J. Ablowitz, G. Biondini and S. Chakravarty, February 1998.

#344 *Computing Periodic Orbits Using the Anti-integrable Limit*, by D. Sterling and J.D. Meiss, February 1998.

#345 *Multidimensional Optical Pulses in Non-resonant Quadratic Materials*, by M.J. Ablowitz, G. Biondini, and S. Blair, February 1998.

#346 *Collision-induced Timing Jitter in Dispersion-managed Soliton Systems*, by M.J. Ablowitz, G. Biondini, S. Chakravarty and R. Horne, February 1998.

#347 *A New Class of Stable Time Discretization Schemes for the Solution of Nonlinear PDEs*, by G. Beylkin, J.M. Keiser and L. Vozovoi, March 1998.

#348 *Recurrence Plots of Experimental Data: To Embed or Not to Embed?* by J. Iwanski and E. Bradley, March 1998.

#349 *On Discretization of the Vector Nonlinear Schrödinger Equation*, by M.J.Ablowitz, Y. Ohta and A.D. Trubatch, March 1998.

#350 *On Integrability and Chaos in Discrete Systems*, by M.J. Ablowitz, Y. Ohta and A.D. Trubatch, March 1998.

#351 *Computing Correctedness: An Exercise in Computational Topology*, by V. Robins, J.D. Meiss and E. Bradley, October 1997.

#352 *Some Steady Vortex Flows Past a Circular Cylinder*, by B. Fornberg, A. Elcrat, M. Horn and K. Miller, April, 1998.

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#375   *The Darboux-Halphen System and the Singularity Structure of its Solutions*, by M.J. Ablowitz, S. Chakravarty, and R. Halburd, May 1998.

#376   *First-order System Least Squares for the Stokes Equations, with Application to Linear Elasticity*, Z. Cai, T. Manteuffel and S. McCormick, October 1997.

#377   *Analysis of Velocity-flux Least-squares Principles for the Navier-Stokes Equations: Part I*, P. Bochev, Z. Cai, T. Manteuffel and S. McCormick, June 1998.

#378   *First-order System Least-Squares (FOSLS) for the Helmholtz Equation*, B. Lee, T.A. Manteuffel, S.F. McCormick, and J. Ruge, May 1998.

#379   *First-order System Least Squares for the Stokes and Linear Elasticity Equations: Further Results*, Z. Cai, C.O. Lee, T.A. Manteuffel, and S.F. McCormick, May 1998.

#380   *First-order System Least Squares for Linear Elasticity: Numerical Results*, Z. Cai, C.O. Lee, T.A. Manteuffel, and S.F. McCormick, May 1998.

#381   *Robustness and Scalability of Algebraic Multigrid*, A.J. Cleary, R.D. Falgout, V. Emden Henson, J.E. Jones, T.A. Manteuffel, S.F. McCormick, G.N. Miranda and J. W. Ruge, May 1998.

#382   *Parallel Multigrid Methods*, J. Jones and S. McCormick, August 1997.

#383   *Local Error Estimates and Adaptive Refinement for First-order System Least Squares (FOSLS)*, M. Berndt, T.A. Manteuffel, and S.F. McCormick, March 1998.

#384   *Analysis of Velocity-flux Least-squares Principles for the Navier-Stokes Equations: Part II*, P. Bochev, Z. Cai, T. Manteuffel, and S. McCormick, October 1998.

#385   *Relaxed Newton's Method: An Elementary Example with Complicated Dynamics*, L. Billings, J.H. Curry and V. Robins, June 1998.

#386   *Symbolic Dynamics and the Discrete Variational Principle*, H.R. Dullin, April 1998.

#387   *Stability of Minimal Periodic Orbits*, by H.R. Dullin and J.D. Meiss, March 1998.

#388   *Quadratic Volume Preserving Maps: an Extension of a Result of Moser*, by K.E. Lenz, H.E. Lomeli and J.D. Meiss, July 1998.