VOLUME 360 NUMBER 9

SEPTEMBER 2008

WHOLE NUMBER 880

TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY

EDITED BY

Dan Abramovich
Alejandro Adem
Richard F. Bass
Mark Feighn
Robert Guralnick, Managing Editor
Lisa C. Jeffrey
Yunping Jiang
Alexander Kleshchev
Steffen Lempp
William P. Minicozzi II
V. Kumar Murty
Alexander Nagel
Peter Polacik
Gustavo Ponce
Jonathan Rogawski
Dimitri Shlyakhtenko
Robert J. Stanton
John R. Stembridge
Daniel Tataru
Mina Teicher

PROVIDENCE, RHODE ISLAND USA

ISSN 0002-9947

Available electronically at
www.ams.org/tran/

Transactions of the American Mathematical Society

This journal is devoted entirely to research in pure and applied mathematics.

Submission information. See **Information for Authors** at the end of this issue.

Publisher Item Identifier. The Publisher Item Identifier (PII) appears at the top of the first page of each article published in this journal. This alphanumeric string of characters uniquely identifies each article and can be used for future cataloging, searching, and electronic retrieval.

Postings to the AMS website. Articles are posted to the AMS website individually after proof is returned from authors and before appearing in an issue.

Subscription information. *Transactions of the American Mathematical Society* (ISSN 0002-9947) is published monthly. Beginning in January 1996 *Transactions* is accessible from `www.ams.org/journals/`. Subscription prices for Volume 360 (2008) are as follows: for paper delivery, US$1814 list, US$1451 institutional member, US$1633 corporate member; for electronic delivery, US$1633 list, US$1306 institutional member, US$1470 corporate member. Upon request, subscribers to paper delivery of this journal are also entitled to receive electronic delivery. If ordering the paper version, add US$49 for surface delivery outside the United States and India; US$53 to India. Expedited delivery to destinations in North America is US$79; elsewhere US$144. For paper delivery a late charge of 10% of the subscription price will be imposed upon orders received from nonmembers after January 1 of the subscription year.

Back number information. For back issues see `www.ams.org/bookstore`.

Subscriptions and orders should be addressed to the American Mathematical Society, P.O. Box 845904, Boston, MA 02284-5904 USA. *All orders must be accompanied by payment.* Other correspondence should be addressed to 201 Charles Street, Providence, RI 02904-2294 USA.

Copying and reprinting. Material in this journal may be reproduced by any means for educational and scientific purposes without fee or permission with the exception of reproduction by services that collect fees for delivery of documents and provided that the customary acknowledgment of the source is given. This consent does not extend to other kinds of copying for general distribution, for advertising or promotional purposes, or for resale. Requests for permission for commercial use of material should be addressed to the Acquisitions Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA. Requests can also be made by e-mail to `reprint-permission@ams.org`.

Excluded from these provisions is material in articles for which the author holds copyright. In such cases, requests for permission to use or reprint should be addressed directly to the author(s). (Copyright ownership is indicated in the notice in the lower right-hand corner of the first page of each article.)

Transactions of the American Mathematical Society is published monthly by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2294 USA. Periodicals postage is paid at Providence, Rhode Island. Postmaster: Send address changes to Transactions, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA.

© 2008 by the American Mathematical Society. All rights reserved.

This journal is indexed in *Mathematical Reviews*, *Zentralblatt MATH*, *Science Citation Index®*, *Science Citation Index™–Expanded*, *ISI Alerting Services℠*, *CompuMath Citation Index®*, and *Current Contents®/Physical, Chemical & Earth Sciences*. This journal is archived in *Portico*.

Printed in the United States of America.

⊗ The paper used in this journal is acid-free and falls within the guidelines established to ensure permanence and durability.

10 9 8 7 6 5 4 3 2 1 13 12 11 10 09 08

TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY

CONTENTS

Vol. 360, No. 9 Whole No. 880 September 2008

Yasuyuki Nagatomo, The twistor sections on the Wolf spaces 4497
Lê Tuân Hoa, Finiteness of Hilbert functions and bounds for Castelnuovo-Mumford regularity of initial ideals 4519
Adam Hammett and Boris Pittel, How often are two permutations comparable? 4541
Usha N. Bhosle and Indranil Biswas, Stable real algebraic vector bundles over a Klein bottle 4569
Stefan Friedl and Taehee Kim, Twisted Alexander norms give lower bounds on the Thurston norm 4597
James Colliander, Justin Holmer, and Nikolaos Tzirakis, Low regularity global well-posedness for the Zakharov and Klein-Gordon-Schrödinger systems 4619
Juraj Húska, Exponential separation and principal Floquet bundles for linear parabolic equations on general bounded domains: Nondivergence case 4639
Robert C. Dalang, Carl Mueller, and Roger Tribe, A Feynman-Kac-type formula for the deterministic and stochastic wave equations and other p.d.e.'s 4681
Claudio D'Antoni and László Zsidó, Abelian strict approximation in AW^*-algebras and Weyl-von Neumann type theorems 4705
Bong H. Lian, Andrew R. Linshaw, and Bailin Song, Chiral equivariant cohomology II 4739
Mark F. Demers and Carlangelo Liverani, Stability of statistical properties in two-dimensional piecewise hyperbolic maps 4777
Ryoji Kasagawa, On crossed homomorphisms on symplectic mapping class groups 4815
George A. Elliott and Katsunori Kawamura, A Hilbert bundle characterization of Hilbert C*-modules 4841
D. Ghioca and T. J. Tucker, Equidistribution and integral points for Drinfeld modules 4863
Mário J. Edmundo and Arthur Woerheide, Comparison theorems for o-minimal singular (co)homology 4889
Hiroki Matui, Torsion in coinvariants of certain Cantor minimal $\mathbb{Z}^2$-systems 4913
G. Bellettini and G. Fusco, The Γ-limit and the related gradient flow for singular perturbation functionals of Perona-Malik type 4929
Ciprian Demeter, Terence Tao, and Christoph Thiele, Maximal multilinear operators 4989
Halvard Fausk, Generalized Artin and Brauer induction for compact Lie groups 5043

Editorial Information

To be published in the *Transactions*, a paper must be correct, new, nontrivial, and significant. Further, it must be well written and of interest to a substantial number of mathematicians. Piecemeal results, such as an inconclusive step toward an unproved major theorem or a minor variation on a known result, are in general not acceptable for publication.

Papers submitted to the *Transactions* should exceed 10 published journal pages in length. Shorter papers may be submitted to the *Proceedings of the American Mathematical Society*. Published pages are the same size as those generated in the style files provided for $\mathcal{AMS}$-LaTeX or $\mathcal{AMS}$-TeX.

Information on the backlog for this journal can be found on the AMS website starting from `http://www.ams.org/tran`.

In an effort to make articles available as quickly as possible, articles are posted to the AMS website individually after proof is returned from authors and before appearing in an issue.

A Consent to Publish and Copyright Agreement is required before a paper will be published in this journal. After a paper is accepted for publication, the Providence office will send a Consent to Publish and Copyright Agreement to all authors of the paper. By submitting a paper to this journal, authors certify that the results have not been submitted to nor are they under consideration for publication by another journal, conference proceedings, or similar publication.

Information for Authors

Initial submission. The AMS uses Centralized Manuscript Processing for initial submissions. Authors should submit a PDF file using the Initial Manuscript Submission form found at `www.ams.org/cgi-bin/peertrack/submission.pl`, or send one copy of the manuscript to the following address: Centralized Manuscript Processing, TRANSACTIONS OF THE AMS, 201 Charles Street, Providence, RI 02904-2294 USA. If a paper copy is being forwarded to the AMS, indicate that it is for *Transactions* and include the name of the corresponding author, contact information such as email address or mailing address, and the name of an appropriate Editor to review the paper (see the list of Editors below).

The first page of an article must consist of a *descriptive title*, followed by an *abstract* that summarizes the article in language suitable for workers in the general field (algebra, analysis, etc.). The *descriptive title* should be short, but informative; useless or vague phrases such as "some remarks about" or "concerning" should be avoided. The *abstract* should be at least one complete sentence, and at most 300 words. Included with the footnotes to the paper should be the 2000 *Mathematics Subject Classification* representing the primary and secondary subjects of the article. The classifications are accessible from `www.ams.org/msc/`. The list of classifications is also available in print starting with the 1999 annual index of *Mathematical Reviews*. The Mathematics Subject Classification footnote may be followed by a list of *key words and phrases* describing the subject matter of the article and taken from it. Journal abbreviations used in bibliographies are listed in the latest *Mathematical Reviews* annual index. The series abbreviations are also accessible from `www.ams.org/publications/`. To help in preparing and verifying references, the AMS offers MR Lookup, a Reference Tool for Linking, at `www.ams.org/mrlookup/`.

Electronically prepared manuscripts. The AMS encourages electronically prepared manuscripts, with a strong preference for $\mathcal{AMS}$-LaTeX. To this end, the Society has prepared $\mathcal{AMS}$-LaTeX author packages for each AMS publication. Author packages include instructions for preparing electronic manuscripts, samples, and a style file that generates the particular design specifications of that publication series. Articles properly prepared using the $\mathcal{AMS}$-LaTeX style file and the \label and \ref commands automatically enable extensive intra-document linking to the bibliography and other elements of the article for searching electronically on the Web. Because linking must often be added manually to electronically prepared manuscripts in other forms of TeX, using $\mathcal{AMS}$-LaTeX also reduces the amount of technical intervention once the files are received by the AMS. This results in fewer errors in processing and saves the author proofreading time. $\mathcal{AMS}$-LaTeX

papers also move more efficiently through the production stream, helping to minimize publishing costs.

$\mathcal{AMS}$-LaTeX is the highly preferred format of TeX, but author packages are also available in $\mathcal{AMS}$-TeX. Those authors who make use of these style files from the beginning of the writing process will further reduce their own efforts. Manuscripts prepared electronically in LaTeX or plain TeX are normally not acceptable due to the high amount of technical time required to insure that the file will run properly through the AMS in-house production system. LaTeX users will find that $\mathcal{AMS}$-LaTeX is the same as LaTeX with additional commands to simplify the typesetting of mathematics, and users of plain TeX should have the foundation for learning $\mathcal{AMS}$-LaTeX.

Authors may retrieve an author package from the AMS website starting from `www.ams.org/tex/` or via FTP to `ftp.ams.org` (login as `anonymous`, enter username as password, and type `cd pub/author-info`). The *AMS Author Handbook* and the *Instruction Manual* are available in PDF format following the author packages link from `www.ams.org/tex/`. The author package can also be obtained free of charge by sending email to `tech-support@ams.org` (Internet) or from the Publication Division, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA. When requesting an author package, please specify $\mathcal{AMS}$-LaTeX or $\mathcal{AMS}$-TeX and the publication in which your paper will appear. Please be sure to include your complete email address.

After acceptance. The final version of the electronic manuscript should be sent to the Providence office immediately after the paper has been accepted for publication. The author should also send the final version of the paper to the Editor, who will forward a copy to the Providence office. Accepted electronically prepared manuscripts can be submitted via the web at `www.ams.org/submit-book-journal/`, sent via email to `pub-submit@ams.org` (Internet), or sent on diskette to the Electronic Prepress Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA. When sending a manuscript electronically via email or diskette, please be sure to include a message indicating in which publication the paper has been accepted. No corrections will be accepted electronically. Authors must mark their changes on their proof copies and return them to the Providence office. Complete instructions on how to send files are included in the author package.

Electronic graphics. Comprehensive instructions on preparing graphics are available starting from `www.ams.org/jourhtml/authors.html`. A few of the major requirements are given here.

Submit files for graphics as EPS (Encapsulated PostScript) files. This includes graphics originated via a graphics application as well as scanned photographs or other computer-generated images. If this is not possible, TIFF files are acceptable as long as they can be opened in Adobe Photoshop or Illustrator. No matter what method was used to produce the graphic, it is necessary to provide a paper copy to the AMS.

Authors using graphics packages for the creation of electronic art should also avoid the use of any lines thinner than 0.5 points in width. Many graphics packages allow the user to specify a "hairline" for a very thin line. Hairlines often look acceptable when proofed on a typical laser printer. However, when produced on a high-resolution laser imagesetter, hairlines become nearly invisible and will be lost entirely in the final printing process.

Screens should be set to values between 15% and 85%. Screens which fall outside of this range are too light or too dark to print correctly. Variations of screens within a graphic should be no less than 10%.

AMS policy on making changes to articles after posting. Articles are posted to the AMS website individually after proof is returned from authors and before appearing in an issue. To preserve the integrity of electronically published articles, once an article is individually posted to the AMS website but not yet in an issue, changes cannot be made in place in the paper. However, an "Added after posting" section may be added to the paper right before the References when there is a critical error in the content of the paper. The "Added after posting" section gives the author an opportunity to correct this type of critical error before the article is put into an issue for printing and before it is then

reposted with the issue. The "Added after posting" section remains a permanent part of the paper. The AMS does not keep author-related information, such as affiliation, current address, and email address, up to date after a paper is initially posted.

Once the article is assigned to an issue, even if the issue has not yet been posted to the AMS website, corrections may be made to the paper by submitting a traditional errata article. The errata article will appear in a future print issue and will link back and forth on the web to the original article online.

Secure manuscript tracking on the Web. Authors can track their manuscripts through the AMS journal production process using the personal AMS ID and Article ID printed in the upper right-hand corner of the Consent to Publish form sent to each author who publishes in AMS journals. Access to the tracking system is available from `www.ams.org/mstrack/`. An explanation of each production step is provided on the web through links from the manuscript tracking screen. Questions can be sent to `tran-query@ams.org`.

TEX files available upon request. TEX files are available upon request for authors by sending email to `file-request@ams.org` or by contacting the Electronic Prepress Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA. The request should include the title of the paper, the name(s) of the author(s), the name of the publication in which the paper has or will appear, and the volume and issue numbers if known. The TEX file will be sent to the author making the request after the article goes to the printer. If the requestor can receive Internet email, please include the email address to which the file should be sent. Otherwise please indicate a diskette format and postal address to which a disk should be mailed. **Note:** Because TEX production at the AMS sometimes requires extra fonts and macros that are not yet publicly available, TEX files cannot be guaranteed to run through the author's version of TEX without errors. The AMS regrets that it cannot provide support to eliminate such errors in the author's TEX environment.

Inquiries. Any inquiries concerning a paper that has been accepted for publication that cannot be answered via the manuscript tracking system mentioned above should be sent to `tran-query@ams.org` or directly to the Electronic Prepress Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA.

Editors

The AMS uses Centralized Manuscript Processing for initial submissions to AMS journals. Authors should follow instructions listed on the Initial Submission page found at www.ams.org/tran/transubmit.html.

Algebra, ALEXANDER KLESHCHEV, Department of Mathematics, University of Oregon, Eugene, OR 97403-1222 USA; e-mail: ams@noether.uoregon.edu

Algebraic geometry, DAN ABRAMOVICH, Department of Mathematics, Brown University, Box 1917, Providence, RI 02912 USA; e-mail: amsedit@math.brown.edu

Algebraic geometry and its applications, MINA TEICHER, Emmy Noether Research Institute for Mathematics, Bar-Ilan University, Ramat-Gan 52900, Israel; e-mail: teicher@macs.biu.ac.il

Algebraic number theory, V. KUMAR MURTY, Department of Mathematics, University of Toronto, 100 St. George Street, Toronto, Ontario, Canada M5S 3G3; e-mail: murty@math.toronto.edu

Algebraic topology, ALEJANDRO ADEM, Department of Mathematics, University of British Columbia, Room 121, 1984 Mathematics Road, Vancouver, British Columbia, Canada V6T 1Z2; e-mail: transactions@math.ubc.ca

Combinatorics, JOHN R. STEMBRIDGE, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109-1043 USA; e-mail: jrs@umich.edu

Complex analysis and harmonic analysis, ALEXANDER NAGEL, Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706-1313 USA; e-mail: nagel@math.wisc.edu

Differential geometry and global analysis, LISA C. JEFFREY, Department of Mathematics, University of Toronto, Bahen Centre for Information Technology, 40 St. George Street 6th Floor, Toronto, Ontario, Canada M5S 2E4; e-mail: jeffrey@math.toronto.edu

Dynamical systems and ergodic theory and complex analysis, YUNPING JIANG, Department of Mathematics, CUNY Queens College and Graduate Center, 65-30 Kissena Boulevard, Flushing, NY 11367 USA; e-mail: yunping.jiang@qc.cuny.edu

Functional analysis and operator algebras, DIMITRI SHLYAKHTENKO, Department of Mathematics, University of California, Los Angeles, CA 90095 USA; e-mail: shlyakht@math.ucla.edu

Geometric analysis, WILLIAM P. MINICOZZI II, Department of Mathematics, Johns Hopkins University, 3400 N. Charles Street, Baltimore, MD 21218 USA; e-mail: trans@math.jhu.edu

Geometric topology, MARK FEIGHN, Department of Mathematics, Rutgers University, Newark, NJ 07102 USA; e-mail: feighn@andromeda.rutgers.edu

Harmonic analysis, representation theory, and Lie theory, ROBERT J. STANTON, Department of Mathematics, Ohio State University, 231 West 18th Avenue, Columbus, OH 43210-1174 USA; e-mail: stanton@math.ohio-state.edu

Logic, STEFFEN LEMPP, Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706-1388 USA; e-mail: lempp@math.wisc.edu

Number theory, JONATHAN ROGAWSKI, Department of Mathematics, University of California, Los Angeles, CA 90095 USA; e-mail: jonr@math.ucla.edu

Partial differential equations, GUSTAVO PONCE, Department of Mathematics, South Hall, Room 6607, University of California, Santa Barbara, CA 93106 USA; e-mail: ponce@math.ucsb.edu

Partial differential equations and dynamical systems, PETER POLACIK, School of Mathematics, University of Minnesota, Minneapolis, MN 55455 USA; e-mail: polacik@math.umn.edu

Probability and statistics, RICHARD F. BASS, Department of Mathematics, University of Connecticut, Storrs, CT 06269-3009 USA; e-mail: bass@math.uconn.edu

Real analysis and partial differential equations, DANIEL TATARU, Department of Mathematics, University of California, Berkeley, CA 94720 USA; e-mail: tataru@math.berkeley.edu

All other communications to the editors should be addressed to the Managing Editor, ROBERT GURALNICK, Department of Mathematics, University of Southern California, Los Angeles, CA 90089-1113 USA; e-mail: guralnic@math.usc.edu

---

MEMOIRS OF THE AMERICAN MATHEMATICAL SOCIETY

Memoirs is devoted to research in pure and applied mathematics of the same nature as *Transactions*. An issue consists of one or more separately bound research tracts for which the authors provide reproduction copy. Papers intended for *Memoirs* should normally be at least 80 pages in length. *Memoirs* has the same editorial committee as *Transactions*; authors may choose an Editor from the list above upon submission.

TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY

CONTENTS

Vol. 360, No. 9 Whole No. 880 September 2008

Yasuyuki Nagatomo, The twistor sections on the Wolf spaces 4497
Lê Tuân Hoa, Finiteness of Hilbert functions and bounds for Castelnuovo-Mumford regularity of initial ideals 4519
Adam Hammett and Boris Pittel, How often are two permutations comparable? 4541
Usha N. Bhosle and Indranil Biswas, Stable real algebraic vector bundles over a Klein bottle 4569
Stefan Friedl and Taehee Kim, Twisted Alexander norms give lower bounds on the Thurston norm 4597
James Colliander, Justin Holmer, and Nikolaos Tzirakis, Low regularity global well-posedness for the Zakharov and Klein-Gordon-Schrödinger systems 4619
Juraj Húska, Exponential separation and principal Floquet bundles for linear parabolic equations on general bounded domains: Nondivergence case 4639
Robert C. Dalang, Carl Mueller, and Roger Tribe, A Feynman-Kac-type formula for the deterministic and stochastic wave equations and other p.d.e.'s 4681
Claudio D'Antoni and László Zsidó, Abelian strict approximation in AW^*-algebras and Weyl-von Neumann type theorems 4705
Bong H. Lian, Andrew R. Linshaw, and Bailin Song, Chiral equivariant cohomology II 4739
Mark F. Demers and Carlangelo Liverani, Stability of statistical properties in two-dimensional piecewise hyperbolic maps 4777
Ryoji Kasagawa, On crossed homomorphisms on symplectic mapping class groups 4815
George A. Elliott and Katsunori Kawamura, A Hilbert bundle characterization of Hilbert C*-modules 4841
D. Ghioca and T. J. Tucker, Equidistribution and integral points for Drinfeld modules 4863
Mário J. Edmundo and Arthur Woerheide, Comparison theorems for o-minimal singular (co)homology 4889
Hiroki Matui, Torsion in coinvariants of certain Cantor minimal $\mathbb{Z}^2$-systems 4913
G. Bellettini and G. Fusco, The Γ-limit and the related gradient flow for singular perturbation functionals of Perona-Malik type 4929
Ciprian Demeter, Terence Tao, and Christoph Thiele, Maximal multilinear operators 4989
Halvard Fausk, Generalized Artin and Brauer induction for compact Lie groups 5043

Transactions of the American Mathematical Society VOLUME 360 NUMBER 9 PAGES 4497–5066 SEPTEMBER 2008