VOLUME 9 NUMBER 2 APRIL 1996

JOURNAL OF THE

AMERICAN MATHEMATICAL SOCIETY

EDITORS

William Fulton
Benedict H. Gross
Andrew Odlyzko
Elias M. Stein
Clifford Taubes

ASSOCIATE EDITORS

James G. Arthur
Alexander Beilinson
Persi Diaconis
Michael H. Freedman
Joe Harris
Sergio Klainerman
Dusa McDuff
Hugh L. Montgomery
Marina Ratner
Richard Schoen
Richard Stanley
Gang Tian
W. Hugh Woodin

PROVIDENCE, RHODE ISLAND USA

ISSN 0894-0347

Journal of the American Mathematical Society

This journal is devoted to research articles of the highest quality in all areas of pure and applied mathematics.

Subscription information. The *Journal of the American Mathematical Society* is published quarterly. Beginning January 1996 the *Journal of the American Mathematical Society* is accessible from e-MATH via the World Wide Web at the URL `http://www.ams.org/publications/`. Subscription prices for Volume 9 (1996) are as follows: for paper delivery, $174 list, $139 institutional member, $157 corporate member, $104 individual member; for electronic delivery, $157 list, $125 institutional member, $141 corporate member, $94 individual member; for combination paper and electronic delivery, $200 list, $160 institutional member, $180 corporate member, $120 individual member. If ordering the paper product, add $18 for surface delivery outside the United States and India; $18 to India. Expedited delivery to destinations in North America $13; elsewhere $36. 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 the *AMS Catalog of Publications*.

Subscriptions and orders should be addressed to the American Mathematical Society, P.O. Box 5904, Boston, MA 02206-5904. *All orders must be accompanied by payment.* Other correspondence should be addressed to P.O. Box 6248, Providence, RI 02940-6248.

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 Assistant to the Publisher, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. 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.)

The *Journal of the American Mathematical Society* is published quarterly by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2213 and is mailed from Providence, Rhode Island. Second class postage paid at Providence, Rhode Island. Postmaster: Send address changes to Journal of the AMS, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248.

© 1996 by the American Mathematical Society. All rights reserved.
This journal is indexed in *Science Citation Index*®, *SciSearch*®, *Research Alert*®, *CompuMath Citation Index*®, and *Current Contents*®/*Physical, Chemical & Earth Sciences*.
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.
♻ Printed on recycled paper.

10 9 8 7 6 5 4 3 2 1 01 00 99 98 97 96

Editors

Chairman
William Fulton
Department of Mathematics
University of Chicago
5734 University Avenue
Chicago, IL 60637-1514

Benedict H. Gross
Department of Mathematics
Harvard University
Cambridge, MA 02138-2901

Elias M. Stein
Department of Mathematics
Princeton University
Princeton, NJ 08544-1000

Andrew Odlyzko
Room 2C-355
AT & T Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974-2070

Clifford Taubes
Department of Mathematics
Harvard University
Cambridge, MA 02138-2901

Associate Editors

James G. Arthur, University of Toronto
Alexander Beilinson, Massachusetts Institute of Technology
Persi Diaconis, Harvard University
Michael H. Freedman, University of California, San Diego
Joe Harris, Stanford University
Sergio Klainerman, Princeton University
Dusa McDuff, SUNY at Stony Brook
Hugh L. Montgomery, University of Michigan
Marina Ratner, University of California, Berkeley
Richard Schoen, Stanford University
Richard Stanley, Massachusetts Institute of Technology
Gang Tian, Courant Institute, New York University
W. Hugh Woodin, University of California, Berkeley

Assistant to the Editorial Board

Laurie Talbo
Department of Mathematics
University of Chicago
Chicago, IL 60637-1514

Editorial Information

As of December 31, 1995, the backlog for this journal was approximately 3 issues. This estimate is the result of dividing the number of manuscripts for this journal in the Providence office that have not yet gone to the printer on the above date by the average number of articles per issue over the previous twelve months, reduced by the number of issues published in four months (the time necessary for editing and composing a typical issue).

A Copyright Transfer Agreement is required before a paper will be published in this journal. By submitting a paper to this journal, authors certify that the

manuscript has not been submitted to nor is it under consideration for publication by another journal, conference proceedings, or similar publication.

Information for Authors and Editors

The first page must contain a *descriptive title* that is short, but informative; useless or vague phrases such as "some remarks about" or "concerning" should be avoided. Included with the footnotes to the paper, there should be the 1991 *Mathematics Subject Classification* representing the primary and secondary subjects of the article. This may be followed by a list of *key words and phrases* describing the subject matter of the article and taken from it. A list of the numbers may be found in the annual index of *Mathematical Reviews*, published with the December issue starting in 1990, as well as from the electronic service e-MATH [**telnet e-MATH.ams.org** (or **telnet 130.44.1.100**). Login and password are **e-math**]. For journal abbreviations used in bibliographies, see the list of serials in the latest *Mathematical Reviews* annual index. When the manuscript is submitted, authors should supply the editor with electronic addresses if available. These will be printed after the postal address at the end of each article.

Two copies of the paper should be sent directly to one of the Editors and the author should keep one copy.

TEX files available upon request. Authors may request a copy of the TEX files of their papers by sending e-mail to `file-request@ams.org` or by contacting the Editorial Department, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. 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 e-mail, please include the e-mail 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.

Electronically prepared manuscripts. The AMS encourages submission of electronically prepared manuscripts in $\mathcal{AMS}$-TEX or $\mathcal{AMS}$-LATEX because properly prepared electronic manuscripts save the author proofreading time and move more quickly through the production process. To this end, the Society has prepared author packages for each AMS publication. Author packages include instructions for preparing electronic manuscripts, the *AMS Author Handbook*, samples, and a style file that generates the particular design specifications of that publication series for both $\mathcal{AMS}$-TEX and $\mathcal{AMS}$-LATEX.

Those authors who make use of these style files from the beginning of the writing process will further reduce their own efforts. Electronically submitted manuscripts prepared in plain TEX or LATEX 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. Users of plain TEX should have little difficulty learning $\mathcal{AMS}$-TEX, and LATEX users will find that $\mathcal{AMS}$-LATEX is the same as LATEX with additional commands to simplify the typesetting of mathematics.

Authors with FTP access may retrieve an author package from the Society's Internet node `e-math.ams.org` (130.44.1.100). For those without FTP access, the author package can be obtained free of charge by sending e-mail to `pub@ams.org` (Internet) or from the Publication Division, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. When requesting an author package, please specify $\mathcal{A}_{\mathcal{M}}\mathcal{S}$-TEX or $\mathcal{A}_{\mathcal{M}}\mathcal{S}$-LATEX, Macintosh or IBM (3.5) format, and the publication in which your paper will appear. Please be sure to include your complete mailing address.

At the time of submission, authors should indicate if the paper has been prepared using $\mathcal{A}_{\mathcal{M}}\mathcal{S}$-TEX or $\mathcal{A}_{\mathcal{M}}\mathcal{S}$-LATEX and provide the Editor with a paper manuscript that matches the electronic manuscript. 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 manuscript to the Editor, who will forward a copy to the Providence office. Editors will require authors to send their electronically prepared manuscripts to the Providence office in a timely fashion. Electronically prepared manuscripts can be sent via e-mail to `pub-submit@ams.org` (Internet) or on diskette to the Editorial Department, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. When submitting an electronic manuscript, 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 submit files are included in the author package.

Any inquiries concerning a paper that has been accepted for publication should be sent directly to the Editorial Department, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248.

JOURNAL OF THE AMERICAN MATHEMATICAL SOCIETY

CONTENTS

Vol. 9, No. 2 April 1996

Rafe Mazzeo, Daniel Pollack, and Karen Uhlenbeck, Moduli spaces of singular Yamabe metrics 303
Kate Okikiolu, The analogue of the strong Szegö limit theorem on the 2- and 3-dimensional spheres 345
Eckhard Meinrenken, On Riemann-Roch formulas for multiplicities 373
Jonathan Beck and Victor G. Kac, Finite-dimensional representations of quantum affine algebras at roots of unity 391
Rahul Pandharipande, A compactification over $\overline{M}_g$ of the universal moduli space of slope-semistable vector bundles 425
Alexander Beilinson, Victor Ginzburg, and Wolfgang Soergel, Koszul duality patterns in representation theory 473
Aaron Bertram, Georgios Daskalopoulos, and Richard Wentworth, Gromov invariants for holomorphic maps from Riemann surfaces to Grassmannians 529
Carlos E. Kenig, Gustavo Ponce, and Luis Vega, A bilinear estimate with applications to the KdV equation 573
Richard K. Skora, Splittings of surfaces 605