
VOLUME 7 NUMBER 4



OCTOBER 1994

JOURNAL

OF THE

AMERICAN MATHEMATICAL SOCIETY

EDITORS

William Fulton
Benedict H. Gross
H. Blaine Lawson, Jr.
Andrew Odlyzko
Elias M. Stein

ASSOCIATE EDITORS

James G. Arthur
Louis Caffarelli
Persi Diaconis
Gerd Faltings
Michael H. Freedman
Joe Harris
Dusa McDuff
Hugh L. Montgomery
Marina Ratner
Richard Schoen
Richard Stanley
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. Subscription prices for Volume 7 (1994) are \$151 list, \$121 institutional member, \$91 individual member. Subscribers outside the United States and India must pay a postage surcharge of \$8; subscribers in India must pay a postage surcharge of \$18. Expedited delivery to destinations in North America \$13; elsewhere \$36.

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. Individual readers of this publication, and nonprofit libraries acting for them, are permitted to make fair use of the material, such as to copy an article for use in teaching or research. Permission is granted to quote brief passages from this publication in reviews provided the customary acknowledgment of the source is given.

Republication, systematic copying, or multiple reproduction of any material in this publication (including abstracts) is permitted only under license from the American Mathematical Society. Requests for such permission should be addressed to the Manager of Editorial Services, American Mathematical Society, P. O. Box 6248, Providence, RI 02940-6248. Requests can also be made by e-mail to reprint-permission@math.ams.org.

The appearance of the code on the first page of an article in this journal indicates the copyright owner's consent for copying beyond that permitted by Sections 107 or 108 of the U.S. Copyright Law, provided that the fee of \$1.00 plus \$.25 per page for each copy be paid directly to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923. This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale.

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.

© Copyright 1994 by the American Mathematical Society. All rights reserved.

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.

This publication was typeset using $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{T}\mathcal{E}\mathcal{X}$,
the American Mathematical Society's $\mathcal{T}\mathcal{E}\mathcal{X}$ macro system.

10 9 8 7 6 5 4 3 2 1 99 98 97 96 95 94

INDEX TO VOLUME 7

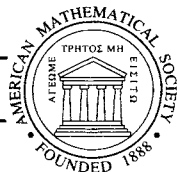
1994

- Björner, Anders and Lovász, László. *Linear decision trees, subspace arrangements, and Möbius functions*, 677
- Bost, J.-B., Gillet, H., and Soulé, C. *Heights of projective varieties and positive Green forms*, 903
- Bousfield, A. K. *Localization and periodicity in unstable homotopy theory*, 831
- Brylinski, Ranee and Kostant, Bertram. *Nilpotent orbits, normality, and Hamiltonian group actions*, 269
- Burns, Daniel M. and Krantz, Steven G. *Rigidity of holomorphic mappings and a new Schwarz lemma at the boundary*, 661
- Caporaso, Lucia. *A compactification of the universal Picard variety over the moduli space of stable curves*, 589
- Dougherty, Randall and Foreman, Matthew. *Banach-Tarski decompositions using sets with the property of Baire*, 75
- Edelman, Alan, Kostlan, Eric, and Shub, Michael. *How many eigenvalues of a random matrix are real?*, 247
- Evans, L. C. and Müller, S. *Hardy spaces and the two-dimensional Euler equations with nonnegative vorticity*, 199
- Foreman, Matthew. See Dougherty, Randall
- Gabai, David. *Homotopy hyperbolic 3-manifolds are virtually hyperbolic*, 193
- Gillet, H. See Bost, J.-B.
- Gover, A. Rod. *Invariants on projective space*, 145
- Kahn, Jeff. *On a problem of Erdős and Lovász. II: $n(r) = O(r)$* , 125
- Kazhdan, D. and Lusztig, G. *Tensor structures arising from affine Lie algebras. III*, 335
- . *Tensor structures arising from affine Lie algebras. IV*, 383
- Kostant, Bertram. See Brylinski, Ranee
- Kostlan, Eric. See Edelman, Alan
- Krantz, Steven G. See Burns, Daniel M.
- Landau, H. J. *The inverse eigenvalue problem for real symmetric Toeplitz matrices*, 749
- Lions, P. L., Perthame, B., and Tadmor, E. *A kinetic formulation of multidimensional scalar conservation laws and related equations*, 169
- Lovász, László. See Björner, Anders
- Lusztig, G. See Kazhdan, D.
- Magidor, Menachem and Shelah, Saharon. *When does almost free imply free? (for groups, transversals, etc.)*, 769
- Martin, D. A. and Steel, J. R. *Iteration trees*, 1
- Minsky, Yair N. *On rigidity, limit sets, and end invariants of hyperbolic 3-manifolds*, 539
- Müller, S. See Evans, L. C.
- Nevo, Amos. *Harmonic analysis and pointwise ergodic theorems for noncommuting transformations*, 875
- Perelman, G. *Manifolds of positive Ricci curvature with almost maximal volume*, 299
- Perthame, B. See Lions, P. L.
- Rosenthal, Haskell. *A characterization of Banach spaces containing c_0* , 707
- Shelah, Saharon. See Magidor, Menachem
- Shub, Michael. See Edelman, Alan
- Sigal, I. M. and Soffer, A. *Asymptotic completeness of N -particle long-range scattering*, 307
- Soffer, A. See Sigal, I. M.
- Soulé, C. See Bost, J.-B.
- Steel, J. R. See Martin, D. A.
- Tadmor, E. See Lions, P. L.

INDEX TO VOLUME 7

- Talagrand, M. *Matching theorems and empirical discrepancy computations using majorizing measures*, 455
- Wooley, Trevor D. *Quasi-diagonal behaviour in certain mean value theorems of additive number theory*, 221
- Zimmer, Robert J. *Discrete groups and non-Riemannian homogeneous spaces*, 159

VOLUME 7



1994

JOURNAL

OF THE

AMERICAN MATHEMATICAL SOCIETY

EDITORS

William Fulton
Benedict H. Gross
H. Blaine Lawson, Jr.
Andrew Odlyzko
Elias M. Stein

ASSOCIATE EDITORS

James G. Arthur
Louis Caffarelli
Persi Diaconis
Gerd Faltings
Michael H. Freedman
Joe Harris
Dusa McDuff
Hugh L. Montgomery
Marina Ratner
Richard Schoen
Richard Stanley
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. Subscription prices for Volume 7 (1994) are \$151 list, \$121 institutional member, \$91 individual member. Subscribers outside the United States and India must pay a postage surcharge of \$8; subscribers in India must pay a postage surcharge of \$18. Expedited delivery to destinations in North America \$13; elsewhere \$36.

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. Individual readers of this publication, and nonprofit libraries acting for them, are permitted to make fair use of the material, such as to copy an article for use in teaching or research. Permission is granted to quote brief passages from this publication in reviews provided the customary acknowledgment of the source is given.

Republication, systematic copying, or multiple reproduction of any material in this publication (including abstracts) is permitted only under license from the American Mathematical Society. Requests for such permission should be addressed to the Manager of Editorial Services, American Mathematical Society, P. O. Box 6248, Providence, RI 02940-6248. Requests can also be made by e-mail to reprint-permission@math.ams.org.

The appearance of the code on the first page of an article in this journal indicates the copyright owner's consent for copying beyond that permitted by Sections 107 or 108 of the U.S. Copyright Law, provided that the fee of \$1.00 plus \$.25 per page for each copy be paid directly to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923. This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale.

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.

© Copyright 1994 by the American Mathematical Society. All rights reserved.

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.

This publication was typeset using $\mathcal{A}\mathcal{M}\mathcal{S}\text{-T}\mathcal{E}\mathcal{X}$,
the American Mathematical Society's $\text{T}\mathcal{E}\mathcal{X}$ macro system.

10 9 8 7 6 5 4 3 2 1 99 98 97 96 95 94

**JOURNAL OF THE AMERICAN MATHEMATICAL SOCIETY
CONTENTS**

Vol. 7, No. 1

January 1994

D. A. Martin and J. R. Steel , Iteration trees	1
Randall Dougherty and Matthew Foreman , Banach-Tarski decompositions using sets with the property of Baire	75
Jeff Kahn , On a problem of Erdős and Lovász. II: $n(r) = O(r)$	125
A. Rod Gover , Invariants on projective space	145
Robert J. Zimmer , Discrete groups and non-Riemannian homogeneous spaces	159
P. L. Lions, B. Perthame, and E. Tadmor , A kinetic formulation of multi-dimensional scalar conservation laws and related equations	169
David Gabai , Homotopy hyperbolic 3-manifolds are virtually hyperbolic	193
L. C. Evans and S. Müller , Hardy spaces and the two-dimensional Euler equations with nonnegative vorticity	199
Trevor D. Wooley , Quasi-diagonal behaviour in certain mean value theorems of additive number theory	221
Alan Edelman, Eric Kostlan, and Michael Shub , How many eigenvalues of a random matrix are real?	247

Vol. 7, No. 2

April 1994

Ranee Brylinski and Bertram Kostant , Nilpotent orbits, normality, and Hamiltonian group actions	269
G. Perelman , Manifolds of positive Ricci curvature with almost maximal volume	299
I. M. Sigal and A. Soffer , Asymptotic completeness of N -particle long-range scattering	307
D. Kazhdan and G. Lusztig , Tensor structures arising from affine Lie algebras. III	335
D. Kazhdan and G. Lusztig , Tensor structures arising from affine Lie algebras. IV	383
M. Talagrand , Matching theorems and empirical discrepancy computations using majorizing measures	455

Yair N. Minsky , On rigidity, limit sets, and end invariants of hyperbolic 3-manifolds	539
Lucia Caporaso , A compactification of the universal Picard variety over the moduli space of stable curves	589
Daniel M. Burns and Steven G. Krantz , Rigidity of holomorphic mappings and a new Schwarz lemma at the boundary	661
Anders Björner and László Lovász , Linear decision trees, subspace arrangements, and Möbius functions	677
Haskell Rosenthal , A characterization of Banach spaces containing c_0 ..	707
H. J. Landau , The inverse eigenvalue problem for real symmetric Toeplitz matrices	749

Menachem Magidor and Saharon Shelah , When does almost free imply free? (for groups, transversals, etc.)	769
A. K. Bousfield , Localization and periodicity in unstable homotopy theory	831
Amos Nevo , Harmonic analysis and pointwise ergodic theorems for non-commuting transformations	875
J.-B. Bost, H. Gillet, and C. Soulé , Heights of projective varieties and positive Green forms	903

Editors

Chairman

H. Blaine Lawson, Jr.
Department of Mathematics
SUNY at Stony Brook
Stony Brook, NY 11794

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

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

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

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

Associate Editors

James G. Arthur, University of Toronto
Louis Caffarelli, Institute for Advanced Study, Princeton
Persi Diaconis, Harvard University
Gerd Faltings, Princeton University
Michael H. Freedman, University of California, San Diego
Joe Harris, Harvard 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
W. Hugh Woodin, University of California, Berkeley

Assistant to the Editorial Board

Sarah W. Jaffe
Department of Mathematics
Harvard University
Cambridge, MA 02138

Editorial Information

As of June 7, 1994, the backlog for this journal was approximately 1 issue. 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.

Electronically prepared manuscripts. The AMS encourages submission of electronically prepared manuscripts in \LaTeX or \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 “preprint” style files, specifically the amsppt style of \LaTeX and the amsart style of \LaTeX , which will simplify the work of authors and of the production staff. Those authors who make use of these style files from the beginning of the writing process will further reduce their own effort. Electronically submitted manuscripts prepared in plain \TeX or \LaTeX do not mesh properly with the AMS production systems and cannot, therefore, realize the same kind of expedited processing. Users of plain \TeX should have little difficulty learning \LaTeX , and \LaTeX users will find that \LaTeX is the same as \LaTeX with additional commands to simplify the typesetting of mathematics.

Guidelines for Preparing Electronic Manuscripts provides additional assistance and is available for use with either \LaTeX or \LaTeX . Authors with FTP access may obtain *Guidelines* from the Society’s Internet node e-MATH.ams.org (130.44.1.100). For those without FTP access *Guidelines* can be obtained free of charge from the e-mail address guide-elec@math.ams.org (Internet) or from the Customer Services Department, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. When requesting *Guidelines*, please specify which version you want.

At the time of submission, authors should indicate if the paper has been prepared using \LaTeX or \LaTeX . The *Manual for Authors of Mathematical Papers* should be consulted for symbols and style conventions. The *Manual* may be obtained free of charge from the e-mail address cust-serv@math.ams.org or from the Customer Services Department, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. The Providence office should be supplied with a manuscript that corresponds to the electronic file being submitted.

Electronic manuscripts should be sent to the Providence office immediately after the paper has been accepted for publication. They can be sent via e-mail to pub-submit@math.ams.org (Internet) or on diskettes to the Publications Department, American Mathematical Society, P.O. Box 6248, Providence, RI

02940-6248. When submitting electronic manuscripts 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. Authors and editors are encouraged to make the necessary submissions of electronically prepared manuscripts and proof copies in a timely fashion.

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. 7, No. 4

October 1994

Menachem Magidor and Saharon Shelah , When does almost free imply free? (for groups, transversals, etc.)	769
A. K. Bousfield , Localization and periodicity in unstable homotopy theory	831
Amos Nevo , Harmonic analysis and pointwise ergodic theorems for non-commuting transformations	875
J.-B. Bost, H. Gillet, and C. Soulé , Heights of projective varieties and positive Green forms	903



0894-0347(199410)7:4;1-X