

AMERICAN MATHEMATICAL SOCIETY

EDITED BY

Vitaly Bergelson

Richard Canary

Lucia Caporaso

Ted C. Chinburg

Henri Darmon, Managing Editor

Ailana M. Fraser

Jim Haglund

Michael Hill

Radha Kessar

Davar Khoshnevisan

Alexander A. Kiselev

Joachim Krieger

Svitlana Mayboroda

Ian Melbourne

Irena Peeva

Robin Pemantle

Lillian B. Pierce

Mariya Ivanova Soskova

Stefaan Vaes

Monica Visan



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.

Publication on the AMS website. Articles are published on the AMS website individually after proof is returned from authors and before appearing in an issue.

Subscription information. Transactions of the American Mathematical Society is published monthly and is also accessible electronically from www.ams.org/journals/. Subscription prices for Volume 374 (2021) are as follows: for paper delivery, US\$2974 list, US\$2379.20 institutional member, US\$2676.60 corporate member; for electronic delivery, US\$2617 list, US\$2093.60 institutional member, US\$2355.30 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\$12 for delivery within the United States; US\$75 for delivery outside the United States. Subscription renewals are subject to late fees. See www.ams.org/journal-faq for more journal subscription information.

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

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 02904-2213 USA.

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 is permitted only under license from the American Mathematical Society. Requests for permission to reuse portions of AMS publication content are handled by the Copyright Clearance Center. For more information, visit www.ams.org/publications/pubpermissions.

Excluded from these provisions is material for which the author holds copyright. In such cases, requests for permission to reuse or reprint material 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 (ISSN 0002-9947 (print); ISSN 1088-6850 (online)) is published monthly by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2213 USA. Periodicals postage is paid at Providence, Rhode Island. Postmaster: Send address changes to Transactions, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2213 USA.

© 2021 by the American Mathematical Society. All rights reserved.

This journal is indexed in Mathematical Reviews, Zentralblatt MATH, Science Citation Index[®], Science Citation IndexTM–Expanded, ISI Alerting ServicesSM, CompuMath Citation Index[®], and Current Contents[®]/Physical, Chemical & Earth Sciences. This journal is archived in Portico and in CLOCKSS.

Printed in the United States of America.

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

TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY CONTENTS

Vol.	374, No. 1	Whole No. 1040	January 2	2021
Ana	of nonnegative se	David González-Álvaro, Moduli spectional or positive Ricci curvature on	homotopy real	-
ъ.]
Kice		eika Fukuizumi, and Justin Holmer cal point NLS		3!
R 113		ence Galois groups under specialization		6
	gwei Li, José Ombrosi, and	María Martell, Henri Martika Emil Vuorinen, End-point estimates luckenhoupt classes, and applications.	inen, Sheldy s, extrapolation	9'
c (eker, and F. Merlevède, Rates of		Э
·. ·	invariance princip	ples for random walks on linear groups	via martingale	13'
Mar	rie Albenque, l	Laurent Ménard, and Gilles Scl	haeffer, Local	
Mic		rge random triangulations coupled with loes spatial homogeneity ultimately pre		17!
IVIIC	taxis systems?	A paradigm for structure support by	rapid diffusion	01/
7		nomous parabolic flow o Xiao, Dimensions of automorphism		21
Zey		neations of F -cyclic F -crystals		26
Wei		chinnikov, Gleb Pogudin, and Tho		20
****	Elimination of ur	nknowns for systems of algebraic difference	ential-difference	30
Mar	•	Antoine Mottet, Miroslav Olšák, J		00
	Michael Pinsk	$ \frac{1}{2} $ and Ross Willard, ω -categor identities	rical structures	32
Hyu	ık Jun Kweon,	Bounds on the torsion subgroups of		35
Fu I	· .	man, Montserrat Teixidor i Bigas,	and Naizhen	00
	•	near series and ranks of multiplication r		36
Xin		Rongchan Zhu, and Xiangchan Z		
	heat equations fo	or infinite strings with values in a manif	fold	40
Assa	af Shani, Borel re	educibility and symmetric models		45
Vict	or Arnaiz and A	Ángel Castro, Singularity formation for	or the fractional	
	Euler-alignment	system in 1D		48
Piot		he number of tame concealed convex s		
		ras		51
Isab		Giulio Galise, and Hitoshi Ishii, P		
		degenerate elliptic equations and the st		53
Roh	•	lgebraic stability of meromorphic maps ack maps		56
Ana		and Changho Han, Stable log surfa		
	covers, and canon	nical curves of genus 4		58
Ariı	ndam Roy and A	Akshaa Vatwani, Zeros of Dirichlet p	olynomials	64

Stanisław Spodzieja, A geometric model of an arbitrary differentially closed					
field of characteristic zero	661				
Jinwon Choi, Michel van Garrel, Sheldon Katz, and Nobuyoshi					
Takahashi, Log BPS numbers of log Calabi-Yau surfaces	685				
Andrew Bridy, John R. Doyle, Dragos Ghioca, Liang-Chung Hsia,					
and Thomas J. Tucker, Finite index theorems for iterated Galois					
groups of unicritical polynomials	731				
Monroe Eskew and Yair Hayut, Erratum for "On the consistency of local					
and global versions of Chang's Conjecture"	751				

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 be 15 or more 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 AMS-INTEX.

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 electronically published on the AMS website individually after proof is returned from authors and before appearing in an issue.

A Consent to Publish is required before we can begin processing your paper. After a paper is accepted for publication, the Providence office will send a Consent to Publish 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. All articles submitted to this journal are peer reviewed. The AMS has a single blind peer-review process in which the reviewers know who the authors of the manuscript are, but the authors do not have access to the information on who the reviewers are. 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/submission/tran, or send one copy of the manuscript to the following address: Centralized Manuscript Processing, TRANSACTIONS OF THE AMS, 201 Charles Street, Providence, RI 02904-2213 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 2010 Mathematics Subject Classification representing the primary and secondary subjects of the article. The classifications are accessible from www.ams.org/msc/. 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/msnhtml/serials.pdf. 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. Manuscripts should be electronically prepared in $\mathcal{A}_{\mathcal{M}}\mathcal{S}$ -LaTeX. To this end, the Society has prepared $\mathcal{A}_{\mathcal{M}}\mathcal{S}$ -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 $\mathcal{A}_{\mathcal{M}}\mathcal{S}$ -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.

Authors may retrieve an author package for *Transactions of the AMS* from www.ams.org/tran/tranauthorpac.html. The *AMS Author Handbook* is available in PDF

format from the author package link. The author package can also be obtained free of charge by sending email to tech-support@ams.org, or from the Publication Division, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2213 USA. When requesting an author package, please specify the publication in which your paper will appear. Please be sure to include your complete email address.

After acceptance. The source files for 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 submit a PDF of 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, or sent on CD to the Electronic Prepress Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2213 USA. When sending a manuscript electronically via email or CD, please be sure to include a message indicating in which publication the paper has been accepted. 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/authors/journals.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.

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%.

Any graphics created in color will be rendered in grayscale for the printed version unless color printing is authorized by the Managing Editor and the Publisher. In general, color graphics will appear in color in the online version.

AMS policy on making changes to articles after publication. Articles are published on 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 published to the AMS website, changes cannot be made in place in 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 electronically published.

Corrections of critical errors may be made to the paper by submitting an errata article to the Editor. The errata article will be published electronically, will appear in a future print issue, and will link back and forth on the Web with the original article.

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.

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 02904-2213 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.

Managing Editor: Henri Darmon, Department of Mathematics, McGill University, Montreal, Quebec H3A 0G4, Canada; e-mail: darmon@math.mcgill.ca

1. GEOMETRY, TOPOLOGY & LOGIC

Coordinating Editor: Richard Canary, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109-1043 USA; e-mail: canary@umich.edu

Algebraic topology, Michael Hill, Department of Mathematics, University of California Los Angeles, Los Angeles, CA 90095 USA; e-mail: mikehill@math.ucla.edu

Logic, Mariya Ivanova Soskova, Department of Mathematics, University of Wisconsin-Madison, Madison, WI 53706 USA; e-mail: msoskova@math.wisc.edu

Low-dimensional topology and geometric structures, Richard Canary

2. ALGEBRA AND NUMBER THEORY

Coordinating Editor: Henri Darmon, Department of Mathematics, McGill University, Montreal, Quebec H3A 0G4, Canada; e-mail: darmon@math.mcgill.ca

Algebra, Radha Kessar, Department of Mathematics, City, University of London, London EC1V 0HB, United Kingdom; e-mail: radha.kessar.l@city.ac.uk

Algebraic geometry, Lucia Caporaso, Department of Mathematics and Physics, Roma Tre University, Largo San Leonardo Murialdo, I-00146 Rome, Italy; e-mail: LCedit@mat.uniroma3.it

Analytic number theory, Lillian B. Pierce, Department of Mathematics, Duke University, 120 Science Drive Box 90320, Durham, NC 27708 USA; e-mail: pierce@math.duke.edu

Arithmetic geometry, Ted C. Chinburg, Department of Mathematics, University of Pennsylvania, Philadelphia, PA 19104-6395 USA; e-mail: ted@math.upenn.edu

Commutative algebra, Irena Peeva, Department of Mathematics, Cornell University, Ithaca, NY 14853 USA; e-mail: irena@math.cornell.edu

Number theory, Henri Darmon

3. GEOMETRIC ANALYSIS & PDE

Coordinating Editor: Alexander A. Kiselev, Department of Mathematics, Duke University, 120 Science Drive, Rm 117 Physics Bldg, Durham, NC 27708 USA; e-mail: kiselev@math.duke.edu

Differential geometry and geometric analysis, Ailana M. Fraser, Department of Mathematics, University of British Columbia, 1984 Mathematics Road, Room 121, Vancouver BC V6T 1Z2, Canada; e-mail: afraser@math.ubc.ca

Harmonic analysis and partial differential equations, Monica Visan, Department of Mathematics, University of California Los Angeles, 520 Portola Plaza, Los Angeles, CA 90095 USA; e-mail: visan@math.ucla.edu

Partial differential equations and functional analysis, Alexander A. Kiselev

Real analysis and partial differential equations, Joachim Krieger, Bâtiment de Mathématiques, École Polytechnique Fédérale de Lausanne, Station 8, 1015 Lausanne Vaud, Switzerland; e-mail: joachim.krieger@epfl.ch

4. ERGODIC THEORY, DYNAMICAL SYSTEMS & COMBINATORICS

Coordinating Editor: Vitaly Bergelson, Department of Mathematics, Ohio State University, 231 W. 18th Avenue, Columbus, OH 43210 USA; e-mail: vitaly@math.ohio-state.edu

Algebraic and enumerative combinatorics, Jim Haglund, Department of Mathematics, University of Pennsylvania, Philadelphia, PA 19104 USA; e-mail: jhaglund@math.upenn.edu

Probability theory, Robin Pemantle, Department of Mathematics, University of Pennsylvania, 209 S. 33rd Street, Philadelphia, PA 19104 USA; e-mail: pemantle@math.upenn.edu

Dynamical systems and ergodic theory, Ian Melbourne, Mathematics Institute, University of Warwick, Coventry CV4 7AL, United Kingdom; e-mail: I.Melbourne@warwick.ac.uk

Ergodic theory and combinatorics, Vitaly Bergelson

5. ANALYSIS, LIE THEORY & PROBABILITY

Coordinating Editor: Stefaan Vaes, Department of Mathematics, Katholieke Universiteit Leuven, Celestijnenlaan 200B, B-3001 Leuven, Belgium; e-mail: stefaan.vaes@wis.kuleuven.be

Functional analysis and operator algebras, Stefaan Vaes

Harmonic analysis, PDEs, and geometric measure theory, Svitlana Mayboroda, School of Mathematics, University of Minnesota, 206 Church Street SE, 127 Vincent Hall, Minneapolis, MN 55455 USA; e-mail: svitlana@math.umn.edu

Probability theory and stochastic analysis, Davar Khoshnevisan, Department of Mathematics, The University of Utah, Salt Lake City, UT 84112 USA; e-mail: davar@math.utah.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.

$({\it Continued from back cover})$

Isabeau Birindelli, Giulio Galise, and Hitoshi Ishii, Positivity sets of supersolutions of degenerate elliptic equations and the strong maximum	
principle	537
Rohini Ramadas, Algebraic stability of meromorphic maps descended from	
Thurston's pullback maps	563
Anand Deopurkar and Changho Han, Stable log surfaces, admissible	
covers, and canonical curves of genus 4	587
Arindam Roy and Akshaa Vatwani, Zeros of Dirichlet polynomials	641
Stanisław Spodzieja, A geometric model of an arbitrary differentially closed	
field of characteristic zero	661
Jinwon Choi, Michel van Garrel, Sheldon Katz, and Nobuyoshi	
Takahashi, Log BPS numbers of log Calabi-Yau surfaces	685
Andrew Bridy, John R. Doyle, Dragos Ghioca, Liang-Chung Hsia, and Thomas J. Tucker, Finite index theorems for iterated Galois	
groups of unicritical polynomials	731
Monroe Eskew and Yair Hayut, Erratum for "On the consistency of local	
and global versions of Chang's Conjecture"	751

TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY CONTENTS

Vol. 374, No. 1	Whole No. 1040	January 202
of nonnegative secti	avid González-Álvaro, Moduli onal or positive Ricci curvature o	on homotopy real
Riccardo Adami, Reika	a Fukuizumi, and Justin Holm point NLS	ner, Scattering for
Ruyong Feng, Difference	e Galois groups under specializati	ion 6
Ombrosi, and Em	Iaría Martell, Henri Martil nil Vuorinen, End-point estimat tenhoupt classes, and applications	tes, extrapolation
invariance principles	r, and F. Merlevède, Rates of sfor random walks on linear grou	ps via martingale
	rent Ménard, and Gilles S	
	random triangulations coupled wi	
taxis systems? A p	spatial homogeneity ultimately poradigm for structure support brooks parabolic flow	y rapid diffusion
Zeyu Ding and Xiao X	Kiao, Dimensions of automorphis tions of F -cyclic F -crystals	sm group schemes
Wei Li, Alexey Ovchir Elimination of unkn	nnikov, Gleb Pogudin, and Thomas for systems of algebraic difference	homas Scanlon, erential-difference
Manuel Bodirsky, Ant Michael Pinsker,	$egin{array}{lll} { m coine \ Mottet, \ Miroslav \ Olšák,} \ { m and \ Ross \ Willard, \ ω-categ} \ { m entities} & \ldots & \ldots \end{array}$, Jakub Opršal, gorical structures
	ounds on the torsion subgroups	
	· · · · · · · · · · · · · · · · · · ·	2
Fu Liu, Brian Osserma	n, Montserrat Teixidor i Biga	as, and Naizhen
	series and ranks of multiplication	
	ongchan Zhu, and Xiangchan afinite strings with values in a ma	
Assaf Shani, Borel redu	cibility and symmetric models	45
	gel Castro, Singularity formation tem in 1D	
Piotr Malicki, On the	number of tame concealed convex	subcategories in
		ed on inside back cover
	(2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	







