

## A M E R I C A N M A T H E M A T I C A L S O C I E T Y

## **EDITED BY**

Dan Abramovich, Managing Editor

Tim Austin Clark Barwick Richard Canary Sylvie Corteel Henri Darmon Jacob Fox

Krzysztof Frączek Nikos Frantzikinakis Jim Haglund

Jennifer Hom Yael Karshon David Kerr Radha Kessar Davar Khoshnevisan Dimitris Koukoulopoulos Joachim Krieger
Francesco Maggi
Eugenia Malinnikova
Magdalena Musat
Andrea R. Nahmod
Daniel Nakano
Irena Peeva
Robin Pemantle
Ehud de Shalit
Christina Sormani
Mariya Ivanova Soskova

Daniel Krashen

Monica Visan Ben Weinkove Craig Westerland



## 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. The Transactions of the American Mathematical Society is published monthly and is also accessible electronically from www.ams.org/journals. Individual subscription prices for Volume 376 (2023) are as follows. For electronic only: non-member, US\$2696. For paper delivery: non-member, US\$3063. Add US\$20 for delivery within the United States; US\$90 for surface delivery outside the United States. Upon request, subscribers to paper delivery of this journal are also entitled to receive electronic delivery. For information on institutional pricing, please visit https://www.ams.org/publications/journals/subscriberinfo. 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.

© 2023 by the American Mathematical Society. All rights reserved.

This journal is indexed in Mathematical Reviews, Zentralblatt MATH, Science Citation  $Index^{\mathbb{B}}$ , Science Citation  $Index^{\mathrm{TM}}$ –Expanded, ISI Alerting Services  $^{\mathrm{SM}}$ , CompuMath Citation  $Index^{\mathbb{B}}$ , and Current Contents  $^{\mathbb{B}}$ /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. 376, No. 11	Whole No. 1074	November	2023
	Steve Zelditch, Centrally symmet trally determined in this class		7521
gang Staubach,	vador Rodríguez-López, David i Multilinear oscillatory integrals and ispersive PDEs	estimates for cou-	7555
	d Alden Walker, Two simultaneo		, , , ,
	oups		7603
Smoluchowski-Kr	Mengzi Xie, On the small no camers approximation of nonlinear was	ave equations with	7651
	Qi, Categorifying Hecke algebras		1001
	Categoritying Treeke algebras		7691
	Rham theory for the relative comp		7743
	le complex vector bundles over co	* *	
*			7783
-	Zhang, Precise late-time asymptot		
	a subextreme Kerr black hole and		7815
~	ensorship conjecture		1010
•	nig-Pipher operators in sets with un		
	·····	•	7857
Aditya Karnataki a	nd Léo Poyeton, Families of Galo	ois representations	
S. C. C.	es		7911
	Jungwon Lee, Dynamics of Ostrow		
	l Hausdorff dimensions		7947
	aprace and Martin Kassabov, Tapmial rings with property (T) and	-	
	quotients		7983
	sas, Z. Mesyan, J. D. Mitchell		
	, Automatic continuity, unique Polis		
	s on monoids and clones		8023
9	Krzysztof Klosin, $R = T$ theorem	ms for weight one	
			8095
	and Maxime Zavidovique	*	9190
	nimizing orbits of twist maps  aki Tsukamoto, Application of w		8129
	n dimension		8173
	igns of Fourier coefficients of Hecke-		01.0
-			8193
	n Kool, and Sergej Monavari, A D		
crepant resolution	n conjecture on Calabi-Yau 4-folds .		8225

#### **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 2020 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: Dan Abramovich, Department of Mathematics, Brown University, Providence, RI 02912 USA; e-mail: Dan\_Abramovich+TAMS@brown.edu

## 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, Craig Westerland, School of Mathematics, University of Minnesota, 206 Church St. SE, Minneapolis, MN 55455 USA; e-mail: cwesterl@umn.edu

Geometric topology, Jennifer Hom, School of Mathematics, Georgia Institute of Technology, 686 Cherry Street, Atlanta, GA 30332 USA; e-mail: jhom6@gatech.edu

Homotopy theory, higher category theory, and geometric applications, Clark Barwick, School of Mathematics, University of Edinburgh, James Clerk Maxwell Building, Peter Guthrie Tait Road, Edinburgh, EH9 3FD, United Kingdom; e-mail: clarkbarAMS@pm.me

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

Symplectic geometry, Yael Karshon, Department of Mathematics, University of Toronto, Toronto, Ontario M5S 2E4, Canada; e-mail: karshon@math.toronto.edu

## 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, Algebraic and Arithmetic Geometry, Daniel Krashen, 3E6 David Rittenhouse Lab., University of Pennsylvania, Department of Mathematics, 209 South 33rd Street, Philadelphia, PA 19104 USA; e-mail: daniel.krashen@gmail.com

Algebraic geometry, Dan Abramovich, Department of Mathematics, Brown University, Providence, RI 02912 USA; e-mail: Dan\_Abramovich+TAMS@brown.edu

Analytic number theory, Dimitris Koukoulopoulos, Université de Montréal, Pavillon André-Aisenstadt, 2920, chemin de la Tour, H3T 1J4, Montréal, QC, Canada; e-mail: dimitris.koukoulopoulos@umontreal.ca

Arithmetic algebraic geometry, Ehud de Shalit, Institute of Mathematics, Hebrew University, Giv'at-Ram, Jerusalem 91904 Israel; e-mail: deshalit@math.huji.ac.il

Associative rings and algebras, category theory, homological algebra, group theory and generalizations, Daniel Nakano, Department of Mathematics, University of Georgia, Athens, Georgia 30602 USA; e-mail: nakano@uga.edu

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

Number theory, Henri Darmon

Representation theory and group theory, Radha Kessar, Department of Mathematics, The Alan Turing Building, The University of Manchester, Oxford Road, Manchester M13 9PL United Kingdom; e-mail: radha.kessar@manchester.ac.uk

## 3. GEOMETRIC ANALYSIS & PDE

Coordinating Editor: Joachim Krieger, Bâtiment de Mathématiques, École Polytechnique Fédérale de Lausanne, Station 8, 1015 Lausanne Vaud, Switzerland; e-mail: joachim.krieger@epfl.ch

Calculus of variations, geometric measure theory, elliptic PDEs, Francesco Maggi, Department of Mathematics, The University of Texas at Austin, 2515 Speedway, Stop C1200, Austin TX 78712-1202 USA; e-mail: maggi@math.utexas.edu

Elliptic and parabolic PDEs, geometric analysis, Ben Weinkove, Mathematics Department, Northwestern University, 2033 Sheridan Rd, Evanston, IL 60201 USA; e-mail: weinkove@math.northwestern.edu

Elliptic PDEs, geometric analysis, Eugenia Malinnikova, Department of Mathematics, Stanford University, Stanford, CA 94305 USA; e-mail: eugeniam@stanford.edu

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

Nonlinear Fourier and harmonic analysis and partial differential equations, Andrea R. Nahmod, Department of Mathematics and Statistics, University of Massachusetts Amherst, 710 N. Pleasant St. Lederle GRT, Amherst, MA 01003 USA; e-mail: nahmod@umass.edu

Real analysis and partial differential equations, Joachim Krieger

Riemannian geometry, metric geometry, mathematical general relativity, and geometric measure theory, Christina Sormani, Lehman College and CUNY Graduate Center, 250 Bedford Park Boulevard West, Bronx, NY 10468 USA; e-mail: sormanic@gmail.com

4. ANALYSIS, DYNAMICS, PROBABILITY AND COMBINATORICS

Coordinating Editor: Jim Haglund, Department of Mathematics, University of Pennsylvania, Philadelphia, PA 19104 USA; e-mail: jhaglund@math.upenn.edu Coordinating Editor: Davar Khoshnevisan, Department of Mathematics, The University of Utah, Salt Lake City, UT 84112 USA; e-mail: davar@math.utah.edu

Algebraic and enumerative combinatorics, Jim Haglund

Analysis, probability and ergodic theory, Tim Austin, Department of Mathematics, University of California, Los Angeles, Los Angeles, CA 90095 USA; e-mail: tim@math.ucla.edu

Combinatorics, Jacob Fox, Department of Mathematics, 450 Jane Stanford Way, Building 380, Stanford, CA 94305 USA; e-mail: jacobfox@stanford.edu

Enumeration, algebraic combinatorics, integrable probability, symmetric functions, Sylvie Corteel, Department of Mathematics, University of California, Berkeley, Berkeley, CA 94720 USA; CNRS, IRIF et Université Paris Cité, Paris, France; e-mail: corteel@berkeley.edu

Ergodic theory and dynamical systems, Krzysztof Frączek, Faculty of Math and Computer Science, Nicolaus Copernicus University, Ul. Chopina 12/18 87-100 Toruń, Poland; e-mail: fraczek@mat.umk.pl

Ergodic theory, applications to combinatorics and number theory, Nikos Frantzikinakis, University of Crete, Rethymno, Crete, Greece; e-mail: frantzikinakis@gmail.com

Functional analysis, groups and operator algebras, analysis in quantum information theory, Magdalena Musat, Department of Mathematical Sciences, University of Copenhagen, Universitetsparken 5, 2100 Copenhagen, Denmark; e-mail: musat@math.ku.dk

Operator algebras and ergodic theory, David Kerr, Mathematisches Institut, University of Münster, Einsteinstrasse 62, 48149 Münster, Germany; e-mail: kerrd@uni-muenster.de

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

Probability theory and stochastic analysis, Davar Khoshnevisan

## 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)	

Ruxi Shi and Masaki Tsukamoto, Application of waist inequality to	
entropy and mean dimension	8173
Jesse Jääsaari, On signs of Fourier coefficients of Hecke-Maass cusp forms	
on $\mathrm{GL}_3$	8193
Yalong Cao, Martijn Kool, and Sergej Monavari, A Donaldson-Thomas	
crepant resolution conjecture on Calabi-Yau 4-folds	8225

## TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY CONTENTS

Vol. 376, No. 11 Whole No. 1074 November	er <b>202</b> 3
Hamid Hezari and Steve Zelditch, Centrally symmetric analytic plandomains are spectrally determined in this class	
Aksel Bergfeldt, Salvador Rodríguez-López, David Rule, and Wolgang Staubach, Multilinear oscillatory integrals and estimates for copled systems of dispersive PDEs	u-
Juliette Bavard and Alden Walker, Two simultaneous actions of b	ig
Sandra Cerrai and Mengzi Xie, On the small noise limit in the Smoluchowski-Kramers approximation of nonlinear wave equations with variable friction	he th
Ben Elias and You Qi, Categorifying Hecke algebras at prime roots unity, part I	
<b>Ma Luo,</b> Algebraic de Rham theory for the relative completion of $\mathrm{SL}_2(\mathbb{Z})$	7743
Yang Hu, Metastable complex vector bundles over complex projection spaces	
Siyuan Ma and Lin Zhang, Precise late-time asymptotics of scalar fie in the interior of a subextreme Kerr black hole and its application Strong Cosmic Censorship conjecture	in
Guy David, Linhan Li, and Svitlana Mayboroda, Small $A_{\infty}$ result for Dahlberg-Kenig-Pipher operators in sets with uniformly rectifiable boundaries	le
Aditya Karnataki and Léo Poyeton, Families of Galois representation and $(\varphi, \tau)$ -modules	ns
Valérie Berthé and Jungwon Lee, Dynamics of Ostrowski skew-production 1. Limit laws and Hausdorff dimensions	et:
Pierre-Emmanuel Caprace and Martin Kassabov, Tame automorphis groups of polynomial rings with property (T) and infinitely man alternating group quotients	sm ny
L. Elliott, J. Jonušas, Z. Mesyan, J. D. Mitchell, M. Morayn and Y. Péresse, Automatic continuity, unique Polish topologies, ar Zariski topologies on monoids and clones	e, nd
Tobias Berger and Krzysztof Klosin, $R = T$ theorems for weight of modular forms	ne
Marie-Claude Arnaud and Maxime Zavidovique, Weak K.A.N. solutions and minimizing orbits of twist maps	M. 8129







