

Proceedings of Symposia in PURE MATHEMATICS

Volume 93

String-Math 2014

String-Math 2014
June 9–13, 2014
University of Alberta
Edmonton, Alberta,
Canada

Vincent Bouchard
Charles Doran
Stefan Méndez-Diez
Callum Quigley
Editors



American Mathematical Society

String-Math 2014

Proceedings of Symposia in PURE MATHEMATICS

Volume 93

String-Math 2014

String-Math 2014
June 9–13, 2014
University of Alberta
Edmonton, Alberta,
Canada

Vincent Bouchard
Charles Doran
Stefan Méndez-Diez
Callum Quigley
Editors



American Mathematical Society
Providence, Rhode Island

2010 *Mathematics Subject Classification*. Primary 14-XX, 18-XX, 19-XX, 22-XX, 53-XX, 58-XX, 81-XX, 81Txx, 83Exx, 83E30.

Library of Congress Cataloging-in-Publication Data

Names: String-Math (Conference) (2014 : Edmonton, Alta.) — Bouchard, Vincent, 1979- editor.

Title: String-Math 2014 : June 9-13, 2014, University of Alberta, Alberta, Canada / Vincent Bouchard [and three others], editors.

Description: Providence, Rhode Island : American Mathematical Society, [2016] — Series: Proceedings of symposia in pure mathematics ; volume 93 — Includes bibliographical references.

Identifiers: LCCN 2015045551 — ISBN 9781470419929 (alk. paper)

Subjects: LCSH: Geometry, Algebraic—Congresses. — Quantum theory—Mathematics—Congresses. — AMS: Algebraic geometry. msc — Category theory; homological algebra. msc — K -theory. msc — Topological groups, Lie groups. msc — Differential geometry. msc — Global analysis, analysis on manifolds. msc — Quantum theory. msc — Quantum theory – Quantum field theory; related classical field theories – Quantum field theory; related classical field theories. msc — Relativity and gravitational theory – Unified, higher-dimensional and super field theories – Unified, higher-dimensional and super field theories. msc — Relativity and gravitational theory – Unified, higher-dimensional and super field theories – String and superstring theories. msc

Classification: LCC QA564 .S77 2014 — DDC 516.3/5–dc23 LC record available at <http://lccn.loc.gov/2015045551>

DOI: <http://dx.doi.org/10.1090/pspum/093>

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 select pages 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.

Republishing, systematic copying, or multiple reproduction of any material in this publication is permitted only under license from the American Mathematical Society. Permissions to reuse portions of AMS publication content are handled by Copyright Clearance Center's RightsLink® service. For more information, please visit: <http://www.ams.org/rightslink>.

Send requests for translation rights and licensed reprints to reprint-permission@ams.org.

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 on the copyright page, or on the lower right-hand corner of the first page of each article within proceedings volumes.

© 2016 by the American Mathematical Society. All rights reserved.

The American Mathematical Society retains all rights
except those granted to the United States Government.

Printed in the United States of America.

⊗ The paper used in this book is acid-free and falls within the guidelines
established to ensure permanence and durability.
Visit the AMS home page at <http://www.ams.org/>

10 9 8 7 6 5 4 3 2 1 21 20 19 18 17 16

Contents

Preface	vii
List of speakers	xi
Plenary Talks from String-Math 2014	
All genus mirror symmetry for toric Calabi-Yau 3-orbifolds BOHAN FANG, CHIU-CHU MELISSA LIU, and ZHENGYU ZONG	1
Symmetries and defects in three-dimensional topological field theory JÜRGEN FUCHS and CHRISTOPH SCHWEIGERT	21
Quantum curves and topological recursion PAUL NORBURY	41
Contributed Talks from String-Math 2014	
A few recent developments in 2d (2,2) and (0,2) theories ERIC SHARPE	67
Codimension two defects and the Springer correspondence ASWIN BALASUBRAMANIAN	89
Higher spin AdS_3 holography and superstring theory THOMAS CREUTZIG, YASUAKI HIKIDA, and PETER B. RØNNE	99
Humbert surfaces and the moduli of lattice polarized K3 surfaces CHARLES F. DORAN, ANDREW HARDER, HOSSEIN MOVASATI, and URSULA WHITCHER	109
Superconformal field theories and cyclic homology RICHARD EAGER	141
Differential K-characters and D-branes FABIO FERRARI RUFFINO	151
Integral pentagon relations for 3d superconformal indices ILMAR GAHRAMANOV and HJALMAR ROSENGREN	167
Wilson surfaces in 6D (2,0) theory and $\text{AdS}_7/\text{CFT}_6$ HIRONORI MORI and SATOSHI YAMAGUCHI	177
Motivic zeta functions of the quartic and its mirror dual JOHANNES NICAISE, D. PETER OVERHOLSER, and HELGE RUDDAT	189

Semistability and instability in products and applications ALEXANDER H. W. SCHMITT	201
Local and relative BPS state counts for del Pezzo surfaces MICHEL VAN GARREL	215
Resurgence and topological strings M. VONK	221
Talks from Satellite Events	
Chern-Simons splitting of 2+1D gauge theories TUNA YILDIRIM	233
A strange family of Calabi-Yau 3-folds HOWARD J. NUER and PATRICK DEVLIN	245
Calabi-Yau threefolds fibred by Kummer surfaces associated to products of elliptic curves CHARLES F. DORAN, ANDREW HARDER, ANDREY Y. NOVOSELTSEV, and ALAN THOMPSON	263
Weighted Hurwitz numbers and hypergeometric τ -functions: an overview J. HARNAD	289
Calabi-Yau threefolds with infinite fundamental group ATSUSHI KANAZAWA	335
Logarithmic invariants of links JUN MURAKAMI	343
Positivity of Hochster theta over \mathbb{C} MOHAMMAD REZA RAHMATI	353
Cohomological Donaldson-Thomas theory BALÁZS SZENDRŐI	363

Preface

The conference ‘String-Math 2014’ was held June 9–13, 2014 at the University of Alberta. This was the fourth in a series of large meetings exploring the interface of mathematics and string theory. This edition of String-Math is the first to include satellite workshops: ‘String-Math Summer School’ (June 2–6, 2014 at the University of British Columbia), ‘Calabi-Yau Manifolds and their Moduli’ (June 14–18, 2014 at the University of Alberta), and ‘Quantum Curves and Quantum Knot Invariants’ (June 16–20, 2014 at the Banff International Research Station). This volume presents the proceedings of the conference and these three satellite workshops.

For mathematics, string theory has been a source of many significant inspirations, ranging from Seiberg-Witten theory in four-manifolds, to enumerative geometry and Gromov-Witten theory in algebraic geometry, to work on the Jones polynomial in knot theory, to recent progress in the geometric Langlands program and the development of derived algebraic geometry and n -category theory. In the other direction, mathematics has provided physicists with powerful tools, ranging from powerful differential geometric techniques for solving or analyzing key partial differential equations, to toric geometry, to K-theory and derived categories in D-branes, to the analysis of Calabi-Yau manifolds and string compactifications, to modular forms and other arithmetic techniques. The depth, power and novelty of the results obtained in both fields thanks to their interaction is truly mind boggling.

The String-Math series of conferences bring together the leading mathematicians and mathematically-minded physicists working in this interface. They are an excellent vehicle for further promoting such interactions, and for giving attendees greater opportunities to cross cultural boundaries, learn aspects of other fields relevant for their research, and advertise important developments to audiences that might not otherwise hear of them or appreciate their importance. The earlier conferences in this series — String-Math 2011 at UPenn, String-Math 2012 at the Hausdorff Center in Bonn, and String-Math 2013 at the Simons Center for Geometry and Physics in Stony Brook — have helped identify and establish mathematical string theory as a new branch of mathematics, facilitated the entry into the field of young researchers and newcomers, and served to record the state of the art in a rapidly evolving field.

The ‘String-Math 2014’ conference was organized by Vincent Bouchard (UAlberta), Thomas Creutzig (UAlberta), Emanuel Diaconescu (UAlberta/Rutgers), Charles Doran (UAlberta), David Favero (UAlberta), Terry Gannon (UAlberta), James Lewis (UAlberta), Andreas Malmendier (Colby/UAlberta), Stefan Mendez-Diez (UAlberta), and Callum Quigley (UAlberta). The ‘String-Math Summer School’ was organized by Jim Bryan (UBC). The ‘Calabi-Yau Manifolds and their

Moduli’ workshop was organized by Charles Doran (UAlberta), Mark Gross (Cambridge), Shinobu Hosono (Tokyo), Conan Leung (CUHK), James Lewis (UAlberta), and Yongbin Ruan (U Michigan). The ‘Quantum Curves and Quantum Knot Invariants’ workshop was organized by Vincent Bouchard (UAlberta), Mikhail Khovanov (Columbia), Motohico Mulase (UC Davis), Alexei Oblomkov (UMass), Marko Stovsic (IST), and Piotr Sulkowski (Caltech). These meetings covered a wide array of topics at the interface of mathematics and high energy physics, including:

- Donaldson-Thomas invariants
- Stable quasimaps and Gromov-Witten invariants
- Mirror symmetry, quantization and topological recursion
- Quantization and knot theory
- Mathematical string phenomenology
- Heterotic mirror symmetry
- New and exotic supersymmetric field theories
- Localization and gauge theory
- Gauge theory and Khovanov homology
- Gauge theory angle at integrability
- Conformal field theory
- Homological mirror symmetry
- Gauged linear sigma models
- Categorical constructions of topological field theories
- Non-perturbative dualities, F-theory
- Wall-crossing formulas
- Geometric Langlands
- Arithmetic of strings
- A-twisted Landau-Ginzburg models
- Topological T duality
- String topology
- Elliptic cohomology
- Perturbative amplitudes in gauge theory
- Superstring scattering amplitudes
- Noncommutative geometry

Altogether, the String-Math 2014 conference brought together approximately 130 mathematicians and physicists. There were 25 invited plenary talks given by leaders in both fields. Additionally, there were 22 contributed talks given in parallel sessions. All the talks are available at the conference web site: <https://sites.google.com/a/ualberta.ca/stringmath2014/>.

The math/strings collaboration is clearly here to stay, and we expect this conference series to continue as long the subject remains active and exciting. The venues and years of the first nine conferences of the String-Math series are:

- String-Math 2011, Philadelphia (Penn), June 6–11, 2011
- String-Math 2012, Bonn (Hausdorff center for Mathematics), July 16–21, 2012
- String-Math 2013, Stony Brook (Simons Center for Geometry and Physics), June 17–21, 2013
- String-Math 2014, Edmonton (U of Alberta), June 9–13, 2014
- String-Math 2015, China (Tsinghua Sanya International Mathematics Forum, Sanya, Hainan, China), Dec 31, 2015–Jan 5, 2016

- String-Math 2016, Paris (Institut Poincaré), June 27–July 2, 2016
- String-Math 2017, Hamburg, Germany, July 24–July 29, 2017.
- String-Math 2018, Japan (Tohoku University)
- String-Math 2019, Sweden (Uppsala University)

The conference benefitted from support obtained from the NSF (grant number: NSF DMS 1401390, String Math Conferences 2014), from the Pacific Institute for the Mathematical Sciences through its Collaborative Research Group in Geometry and Physics (2013–2016), from the University of Alberta and from Perimeter Institute for Theoretical Physics.

The editors of String-Math 2014:

Vincent Bouchard
Charles Doran
Stefan Mendez-Diez
Callum Quigley

List of Speakers for String-Math 2014

List of Plenary Speakers for String-Math 2014

Murad Alim
Harvard University

Matt Ballard
University of South Carolina

Christopher E. Beasley
Northeastern University

Tudor Dimofte
Institute for Advanced Study

John Duncan
Case Western Reserve University

Bertrand Eynard
Saclay

Mathias Gaberdiel
ETH Zurich

Davide Gaiotto
Perimeter Institute

Sylvester James Gates
University of Maryland

Jonathan Heckman
Harvard University

Kentaro Hori
Institute for the Physics and
Mathematics of the Universe

Sheldon Katz
University of Illinois at
Urbana-Champaign

Bumsig Kim
Korea Institute for Advanced Study

Albrecht Klemm
Universität Bonn

Chiu-Chu Melissa Liu
Columbia University

Matilde Marcolli
Caltech

Greg Moore
Rutgers University

David Morrison
University of California, Santa Barbara

Paul Norbury
University of Melbourne

Jonathan Rosenberg
University of Maryland

Yongbin Ruan
University of Michigan

Volker Schomerus
DESY

Christoph Schweigert
Universität Hamburg

Eric Sharpe
Virginia Tech

Claire Voisin
École Polytechnique

List of Contributed Speakers for String-Math 2014

John Dixon
Tabacon

Richard Eager
Tokyo University

Fabio Ferrari Ruffino
Federal University of São Carlos

Ilmar Gahramanov
Humboldt-Universität zu Berlin

Richard Garavuso
Harish-Chandra Research Institute

Yasuaki Hikida
Rikkyo University

Gerald Hoehn
Kansas State University

Martijn Kool
PIMS/University of British Columbia

Peter Koroteev
Perimeter Institute for Theoretical
Physics

Stefan Mendez-Diez
University of Alberta

Hironori Mori
Osaka University

Nicolo Piazzalanga
SISSA/INFN

Helge Ruddat
Johannes Gutenberg-Universität Mainz

Emanuel Scheidegger
Universität Freiburg

Alexander Schmitt
Freie Universität Berlin

Piotr Sułkowski
University of Warsaw

Michel van Garrel
Korea Institute for Advanced Study

Marcel Vonk
University of Amsterdam

Ursula Whitcher
University of Wisconsin-Eau Claire

Simon Wood
Australian National University

Tuna Yildirim
The University of Iowa

Matthew Young
The University of Hong Kong

List of Speakers for the String-Math Summer School

Kevin Costello
Northwestern University

Andy Neitzke
The University of Texas at Austin

Tony Pantev
University of Pennsylvania

Balázs Szendrői
University of Oxford

Eric Zaslow
Northwestern University

List of Speakers for the ‘Calabi-Yau Manifolds and their Moduli’ Workshop

Xi Chen
University of Alberta

David Favero
University of Alberta

Sara Filippini
University of Zurich

Karl Fredrickson
University of California, Riverside

Sergey Galkin
Moscow State University

Andrew Harder
University of Alberta

Atsushi Kanazawa
University of British Columbia/Harvard
University

Tyler Kelly
University of Cambridge

Chiu-Chu Melissa Liu
Columbia University

Andreas Malmendier
Utah State University

Stefan Mendez-Diez
University of Alberta

David Morrison
University of California, Santa Barbara

Howard Nuer
Rutgers University

Andre Perunicic
Queen's University

Mohammad Rahmati
Centro de Investigación en
Matemáticas, A.C.

Helge Ruddat
Johannes Gutenberg-Universität Mainz

Alan Thompson
University of Alberta/University of
Waterloo

Katrin Wendland
Universität Freiburg

Shing-Tung Yau
Harvard University

Noriko Yui
Queen's University

**List of Speakers for the ‘Quantum
Curves and Quantum Knot
Invariants’ Workshop**

Gaëtan Borot
Max-Planck-Institut für Mathematik

Tudor Dimofte
Institute for Advanced Study

Olivia Dumitrescu
University of Leibniz, Hannover

Pavel Etingof
Massachusetts Institute of Technology

Hiroyuki Fuji
Tsinghua University

Stavros Garoufalidis
Georgia Institute of Technology

Victor Ginzburg
University of Chicago

John Harnad
CRM, Université de
Montréal/Concordia University

Lotte Hollands
University of Oxford

Chiu-Chu Melissa Liu
Columbia University

Jun Murakami
Waseda University

Satoshi Nawata
The National Institute for Nuclear
Physics and High Energy Physics,
Amsterdam

Lenny Ng
Duke University

Paul Norbury
University of Melbourne

Alexei Oblomkov
University of Massachusetts

Anne Schilling
University of California, Davis

Marko Stošić
Instituto Superior Técnico, Portugal

Piotr Sułkowski
University of Warsaw

Katrin Wendland
Universität Freiburg

Selected Published Titles in This Series

- 93 **Vincent Bouchard, Charles Doran, Stefan Méndez-Diez, and Callum Quigley, Editors**, *String-Math* 2014, 2016
- 90 **Ron Donagi, Sheldon Katz, Albrecht Klemm, and David R. Morrison, Editors**, *String-Math* 2012, 2015
- 89 **D. Dolgopyat, Y. Pesin, M. Pollicott, and L. Stoyanov, Editors**, *Hyperbolic Dynamics, Fluctuations and Large Deviations*, 2015
- 88 **Ron Donagi, Michael R. Douglas, Ljudmila Kamenova, and Martin Rocek, Editors**, *String-Math* 2013, 2014
- 87 **Helge Holden, Barry Simon, and Gerald Teschl, Editors**, *Spectral Analysis, Differential Equations and Mathematical Physics: A Festschrift in Honor of Fritz Gesztesy's 60th Birthday*, 2013
- 86 **Kailash C. Misra, Daniel K. Nakano, and Brian J. Parshall, Editors**, *Recent Developments in Lie Algebras, Groups and Representation Theory*, 2012
- 85 **Jonathan Block, Jacques Distler, Ron Donagi, and Eric Sharpe, Editors**, *String-Math* 2011, 2012
- 84 **Alex H. Barnett, Carolyn S. Gordon, Peter A. Perry, and Alejandro Uribe, Editors**, *Spectral Geometry*, 2012
- 83 **Hisham Sati and Urs Schreiber, Editors**, *Mathematical Foundations of Quantum Field Theory and Perturbative String Theory*, 2011
- 82 **Michael Usher, Editor**, *Low-dimensional and Symplectic Topology*, 2011
- 81 **Robert S. Doran, Greg Friedman, and Jonathan Rosenberg, Editors**, *Superstrings, Geometry, Topology, and C^* -algebras*, 2010
- 80 **D. Abramovich, A. Bertram, L. Katzarkov, R. Pandharipande, and M. Thaddeus, Editors**, *Algebraic Geometry*, 2009
- 79 **Dorina Mitrea and Marius Mitrea, Editors**, *Perspectives in Partial Differential Equations, Harmonic Analysis and Applications*, 2008
- 78 **Ron Y. Donagi and Katrin Wendland, Editors**, *From Hodge Theory to Integrability and TQFT*, 2008
- 77 **Pavel Exner, Jonathan P. Keating, Peter Kuchment, Toshikazu Sunada, and Alexander Teplyaev, Editors**, *Analysis on Graphs and Its Applications*, 2008
- 76 **Fritz Gesztesy, Percy Deift, Cherie Galvez, Peter Perry, and Wilhelm Schlag, Editors**, *Spectral Theory and Mathematical Physics: A Festschrift in Honor of Barry Simon's 60th Birthday*, 2007
- 75 **Solomon Friedberg, Daniel Bump, Dorian Goldfeld, and Jeffrey Hoffstein, Editors**, *Multiple Dirichlet Series, Automorphic Forms, and Analytic Number Theory*, 2006
- 74 **Benson Farb, Editor**, *Problems on Mapping Class Groups and Related Topics*, 2006
- 73 **Mikhail Lyubich and Leon Takhtajan, Editors**, *Graphs and Patterns in Mathematics and Theoretical Physics*, 2005
- 72 **Michel L. Lapidus and Machiel van Frankenhuysen, Editors**, *Fractal Geometry and Applications: A Jubilee of Benoît Mandelbrot*, 2004
- 71 **Gordana Matić and Clint McCrory, Editors**, *Topology and Geometry of Manifolds*, 2003
- 70 **Michael D. Fried and Yasutaka Ihara, Editors**, *Arithmetic Fundamental Groups and Noncommutative Algebra*, 2002
- 69 **Anatole Katok, Rafael de la Llave, Yakov Pesin, and Howard Weiss, Editors**, *Smooth Ergodic Theory and Its Applications*, 2001
- 68 **Robert S. Doran and V. S. Varadarajan, Editors**, *The Mathematical Legacy of Harish-Chandra*, 2000

For a complete list of titles in this series, visit the
AMS Bookstore at www.ams.org/bookstore/pspumseries/.

ISBN: 978-1-4704-1992-9



PSPUM/93

