

QGM HIGHLIGHTS 2013



AARHUS
UNIVERSITY



Danmarks
Grundforskningsfond
Danish National
Research Foundation



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QGM Retreat, Sandbjerg Estate Oct 2013

WELCOME TO QGM

Centre for Quantum Geometry of Moduli Spaces

QGM was established in 2009 as a Center of Excellence, funded by the Danish National Research Foundation. The research objective is to address fundamental mathematical problems at the interface between geometry and theoretical physics.

Based at Aarhus University and directed by Professor Jørgen Ellegaard Andersen, QGM hosts a strong team of high-profile, internationally acclaimed researchers, and with the continuous generation of groundbreaking results, the Centre is recognized throughout the mathematics community worldwide as one of the leading research institutions within this highly specialized field.

Background and research mission

The role of mathematics in our understanding of nature has been recognized for millenia, and its importance is especially poignant in modern theoretical physics as the cost of experiments escalates, and the mathematical complexity of physical theories increases. QGM set out to become the world-leading center in quantum geometry of moduli spaces at the crucial interface between mathematics and theoretical physics, with the aim of contributing to the mathematical underpinnings of contemporary and future physical theories.

Organization

QGM has on top of the permanent professors at Aarhus University eleven internationally renowned scholars based at other research institutions, who regularly visit QGM and with whom resources and research efforts are shared. The core staff thus comprise:

Prof. Jørgen Ellegaard Andersen, Aarhus University
 Prof. Henning Haahr Andersen, Aarhus University
 Prof. Nicolai Reshetikhin, University of California, Berkeley
 Prof. Edward Frenkel, University of California, Berkeley
 Prof. Denis Auroux, University of California, Berkeley
 Prof. Kontsevich, Maxim, Institut des Hautes Etudes Scientifique
 Prof. Hitchin, Nigel hitchin, University of Oxford
 Prof. Alexander Ritter, University of Oxford
 Prof. Dominic Joyce, University of Oxford
 Prof. Hiroshi Ooguri, Caltech
 Prof. Sergei Gukov, Caltech
 Prof. Anton Kapustin, Caltech
 Prof. Robert Penner, Caltech/IHÉS

The academic profile of the Centre is additionally shaped by a steady population of postdocs and PhD students, some of whom are based at University of Oxford and UC Berkeley, respectively.

Mission statement

- To define quantum field theory as a mathematical entity
- To contribute to the unify quantum theory with quantum gravity

Original main research focus

- The Geometric Langlands Program and Higgs bundle moduli spaces
- Toeplitz operators and geometric quantization of moduli spaces
- Combinatorial models for moduli spaces and quantum moduli spaces
- Quantum representation theory and perturbative invariants

New core areas

- Moduli spaces and macromolecules
- Topological Quantum Field Theory and Topological String Theory
- Quantum computing

New directions

- Wall crossing
- Gauge theory
- Contact geometry
- Symplectic geometry

Conceptual goals

- To significantly advance the understanding of moduli spaces and their quantization
- To train the next generation of scholars and researchers to build the Centre into a world-renowned catalyst for collaborative cutting-edge research
- To develop the quantum geometry of moduli spaces, in order to provide complete mathematical models for a number of quantum field theories

MESSAGE FROM THE DIRECTOR



by Professor
Jørgen Ellegaard Andersen

Dear Reader,

Welcome to the annual QGM Highlights brochure in which we look back on the year just passed - this time: 2013.

First of all I am very pleased to announce that the Danish National Research Foundation (DNRF) in 2013 decided to grant a five-year extension to QGM until 2019. The DNRF's international panel of experts concluded in particular, that QGM has a fantastic, well-functioning collaboration with partners around the world, and the resulting synergy effect means that we jointly have the strongest environment in the world in the study of quantum geometry of moduli spaces (see page 10, 'Concluding remarks').

QGM has already three international partners (IHES Paris, Oxford University and UC Berkeley) and will extend this from Sep 2014 to include a fourth partner - the California Institute of Technology (Caltech). The partnership between QGM and Caltech strengthens QGM's activities at further exciting interfaces between math and physics.

By the extension QGM can also continue its focused research program and its various different research activities - of which many are mentioned in the following pages. In particular I would like to highlight our well-attended masterclasses and conferences (page 8-9) where PhD students, postdocs and professors come from top universities and institutions around the world. Furthermore QGM is in the coming years looking forward to also continue our studies of the correlation between protein folding and quantum field theory, and we are pleased that the DNRF's extension provides an opportunity for this new focus area as well.

The high level of events create a dynamic international environment at the Centre along with the many excellent visitors who wish to join our research team during the year.

In 2013 QGM began a joint collaboration program with our Indian partners at the Chennai Mathematics Institute (CMI) and Tata Institute of Fundamental Research (TIFR).

In March 2014 fifteen QGM researchers visited the CMI and TIFR for one month. During this period also a joint conference was held at Kerala School of Mathematics where all came together. The exchange was a great success and we already look forward to welcome our Indian partners to Denmark in June 2014, where three world-class scholars from CMI and TIFR are giving a masterclass at QGM: Nitin Nitsure, Indranil Biswas & Vikraman Balaji.

I am confident that the years to come will be just as productive as the foregoing, and I am looking forward to continue the collaboration with the many excellent researchers who are associated with QGM. Their undeniable skills and great ambitions have put them in the forefront of the Mathematics scene and earned them recognition and acclaim in their respective fields. I take this opportunity to thank them all for their great efforts.

SCIENTIFIC BREAKTHROUGH



Jørgen E. Andersen published his work on the asymptotic expansion of quantum invariants using the geometric quantization of moduli spaces in a top international Journal.



Jørgen E. Andersen and **Robert C. Penner** together with collaborators Peter Zograf and Nikita Alexeev developed a completely novel simple recursions for enumeration of RNA-diagrams on many backbones. Further together with Aarhus co-workers associated with three DNRF centres of excellence (PUMPKIN; INSPIN & CDNA) they have initiated an extensive program of applications of their classification of protein Hydrogen bonds rotations to the study of protein structures.



Nicolai Reshetikhin made fundamental contributions to the formal semiclassical quantization of classical field theory jointly with Alberto S. Cattaneo and Pavuk Mnev and they applied it to Abelian Chern-Simons theory.



Nigel Hitchin made significant mathematical contributions to the study of mirror symmetry and branes on the moduli space of Higgs bundles. The mirror symmetric pairs of branes concerned are the so-called BAA-branes related to moduli spaces of representations of surface groups into noncompact real forms and BBB branes which are hyperholomorphic bundles supported on hyperkähler submanifolds.



Maxim Kontsevich proposed a new program in mirror symmetry mixing together Fukaya categories and Bridgeland stability conditions. Jointly with L. Katzarkov and F. Heiden he further defined stability conditions on Fukaya categories associated with exponential quadratic differentials on complex curves. Joining G. Dimitrov to this collaboration they introduced a new notion of entropy associated with an endofunctor of a triangulated category, studied the basic properties and related it with previous notions.

STATISTICS

Publications: 36 journal articles, 4 conf. proc., 2 book chapters, 5 theses, 5 qualifying dissertations, 36 preprints, 5 scientific reviews and 3 posters.

QGM events: 3 conferences, 4 masterclasses, 35 seminars, 3 Nielsen Lectures, 6 colloquium, 2 retreats, 56 invited talks

QGM STAFF

- 4 permanent senior staff
- 1 short-term associate professor
- 7 ongoing postdoctoral fellows
- 13 Aarhus-based PhD students
- 4 PhD students based at UC Berkeley
- 4 PhD students based at University of Oxford



Henning.H. Andersen has jointly with G. Lehrer and R. Zhang described the endomorphism rings of certain tensor powers for irreducible Weyl modules, in particular proving their cellularity. He has also in joint work with C. Stroppel obtained explicit generators of the ideals defining fusion rings associated with tilting modules for quantum groups.



Kim Frøyshov has obtained existence results for representations of finitely presented groups into compact Lie groups by pure topological means. The proof are motivated by his study of Bogomolny monopoles on compact 3-manifolds with boundary.



Subhojoy Gupta established in joint work with Shinpei Baba from Caltech that for any surface-group representation into $PSL_2(\mathbb{C})$ the set of projective structures on a surface with that holonomy is dense in the Riemann moduli space of the surface.



PhD student **Jens Kristian Egsgaard** in joint work with former PhD student **Søren Fuglede Jørgensen**, have established that the Jones representations of braid groups when evaluated in $q=-1$ are isomorphic to certain representations constructed from the homology of a branched 2-fold cover of the disc. The results have implications for the $q=-1$ limit of quantum representations of a sphere with marked points.



NEW COLLABORATION PARTNERS

QGM initiated during the summer 2013 a collaborating with Chennai Mathematical Institute (CMI) and TATA Institute of Fundamental Research (TIFR). The program involves joint PhD students, joint postdocs as well as joint events and mutual exchanges.

From Sep 2014 QGM is official partner with the California Institute of Technology (Caltech). The program involves joint postdocs as well as joint events and mutual exchanges.

VISITORS

During 2013, QGM had 194 visitors - all from prominent research institutions around the world, including: Sigeo Ihara (Univ. of Tokyo), Anton Gerasimov (ITEP), Vladimir Fock (Strasbourg Univ.), Peter Zograf (Steklov Inst.), Kenji Ueno (Kyoto Univ.), Rinat Kashaev (Univ. de Genève), Indranil Biswas (Tata Institute), Dick Canary (Univ. of Michigan), Andrés Sambarino (Univ. Paris-Sud), Martin Bridgeman (Boston College), Tudor Dimofte (Caltech), Shing-Tung Yau (Harvard/Tsinghua Univ.), Jürg Fröhlich (ETH Zürich), Dror Bar-Natan (University of Toronto), Leonid Chekhov (Loughborough Univ.), Bertrand Eynard (IPhT), Nicolas Orantin (Instituto Superior Técnico, Lisboa), Sergei Gukov (Caltech) and Don Zagier (MPI)

HELLOS...

As an institution with a glowing reputation for its excellent research, QGM continues to be an attractive workplace for both national and international researchers. Aside from the permanent professors, the Centre hosts a population of 7-8 postdocs and around 15 PhD students at any one time. In 2013, QGM welcomed four new postdocs and five PhD students graduated from the centre.



Niels Leth Gammelgaard
Postdoc, May 2013

Research interest:

- Deformation Quantization
- Geometric Quantization
- Moduli Spaces



Rasmus Villemoes
Postdoc, Dec 2013

Research interest:

- Computational biology
- Moduli spaces
- Mapping class groups



Florian Schätz
Postdoc, Aug 2013

Research interest:

- Deformation theory (formal and smooth)
- Homotopical algebra in topology, geometry and physics,
- Iterated integrals and applications.



Daniel Tubbenhauer
Postdoc, Nov 2013

Research interest:

- Categorification of quantum groups and its applications in representation theory
- Low dimensional topology
- Algebraic geometry
- Algebraic, combinatorial and diagrammatic aspects of categorification.

Facts

- Niels Leth Gammelgaard got his PhD from QGM in 2010 and returns back to QGM from a position in industry
- Florian Schätz comes from a postdoc position at the Mathematics Department of Utrecht University
- Daniel Tubbenhauer comes from a postdoc position at the Courant research center, University Göttingen. Daniel Tubbenhauer is at QGM in a joint postdoc position with the following two Indian research institutes: Chennai Mathematical Institute (CMI) and TATA Institute of Fundamental Research (TIFR).
- Rasmus Villemoes got his PhD from QGM in 2009 followed by a one year postdoc position. He returns back to QGM from a position in industry.

QGM has in 2013 received 104 highly qualified applications for a two-year postdoc position. The position is offered to Yang Huang, who received he's PhD from the University of Southern California in 2012 and since been a postdoc in the Max Planck Institute for Mathematics, Bonn

... AND GOODBYES



Johan Martens
Postdoc

Research interests:

- Algebraic and symplectic geometry
- Moduli spaces of bundles
- Integrable systems

Currently Chancellor's Fellow at
The University of Edinburgh



Hans-Christian Herbig
Postdoc

Research interests:

- The commutative and non-commutative geometry of symplectic quotients

Currently postdoc at
The University of Vienna



Brendan McLellan
Postdoc

Research interests:

- Asymptotic expansion conjecture in particular contact and subriemannian geometry of threemanifolds

Currently Research Instructor at
Northeastern University

Graduated PhD students in 2013

Amit De, Aarhus University (currently Quantitative Analyst at Danske Commodities)

Søren Fuglede Jørgensen, Aarhus University (currently postdoc at Uppsala University)

Theo Johnson-Freyd, UC Berkeley (currently NSF Postdoctoral Fellow and Boas Assistant Professor, Northwestern University)

Laura Schaposnik, University of Oxford (currently J. L. Doob Research Assistant Professor at Illinois at Urbana Champaign)

Dan Berwick-Evans, UC Berkeley (currently Assistant Professor at Stanford University)

Guests

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QGM CALENDAR 2013

Course program

Spring 2013

Graduate courses:

Coxeter Groups and Hecke Algebras by H. H. Andersen
 Knot Theory by Andrew Swann & Brendan McLellan
 Riemann's Zeta function by Alexei Venkov
 Smooth Manifolds, Group Actions and Moduli Spaces, II by
 Jørgen Ellegaard Andersen & Johan Martens
 Calculus Math 1B by Nicolai Reshetikhin

Under graduate courses:

PhD instructor classes
 Tutoring, (Mat-Lab sessions)

Fall 2013

Graduate courses:

Math 185 - Complex analysis by Nicolai Reshetikhin
 Math 275- Quantum Integrable Systems by Nicolai Reshetikhin

PhD course:

Iterated Integrals by Florian Schätz

Bachelor course

Algebra by Henning Haahr Andersen
 Synopsis for B3a: Geometry of Surfaces by Nigel Hitchin

Masterclasses, conferences and workshops



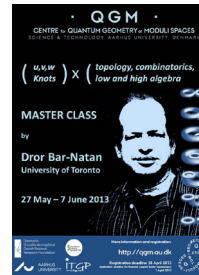
Masterclass: 21-25 Jan

*Recursion from matrix models
 to quantum algebraic geometry*
 by Eynard and Orantin

followed by

Conference: 28 Jan - 1 Feb

Topological recursion and quantum algebraic geometry



Masterclass: 27 May - 7 June

*(u,v,w knots) x (topology, combinatorics,
 low and high algebra)*
 by Dror Bar-Natan



Masterclass: 18-22 March

*Soergel bimodules & Kazhdan-Lusztig
 conjectures*
 by Geordie Williamson &
 Benjamin Elias



Masterclass: 12-16 August

Pressure and Weil-Petersson metrics
 by Bridgeman, Canary & Sambarino

followed by

Conference: 19-22 August

Pressure metric and Higgs bundles



Conference (IHÉS): 14-18 May

Moduli Spaces and Macromolecules
 Organised by
 Jørgen E. Andersen, Aarhus University
 Mikhail Gromov, IHÉS
 Robert Penner, Aarhus University/Caltech



Workshop 2-4 Dec

*Joint iBMath and QGM workshop
 Geometry and topology of macro-
 molecule folding*

QGM seminars and colloquiums

- Jan** Nielsen lecture: Partitions, coverings and modular forms, Don Zagier (MPIM, Bonn University)
- Feb**
- Mar** A global operator approach to WZNW models via Krichever-Novikov type algebras, Martin Schlichenmaier (University of Luxembourg)
 Combinatorial quantum mechanics on graphs, Pavel Mnev (Steklov Institute),
 Towards perturbative topological field theory on manifolds with boundary, Pavel Mnev (Steklov Institute)
 A conjecture relating Heegaard Floer homology and the fundamental group, Liam Watson (University of California, LA (UCLA))
 The Jones polynomial, with a view to Khovanov homology, Liam Watson (University of California, LA (UCLA))
 Floer-Fukaya-Gromov theory and field theory, Yakov Savelyev (CRM-Montreal)
 A purely geometric formulation of quantum homology product, and the proof of its associativity, Yakov Savelyev (CRM-Montreal)
 Understanding the Rubik's cube and similar puzzles, Peter McNamara (Stanford University)
 Representations of KLR Algebras, Peter McNamara (Stanford University)
 Quantum shuffle algebras: cohomologies, deformations and applications, Xin Fang (Institut de Mathématiques de Jussieu)
 J-holomorphic curves in a nef class, Weiyi Zhang (University of Michigan)
- Apr** Adapted complex structures and the geodesic flow, William Kirwin (University of Cologne)
 Higher holonomies and the little disks operad, Florian Schätz (Utrecht University)
 Introduction to quantization, William Kirwin (University of Cologne)
 Geometry and low-dimensional manifolds, Hartmut Weiss (LMU München)
 Rigidity and flexibility of hyperbolic cone-3-manifolds and polyhedra, Hartmut Weiss (LMU München)
- May** The good pants homology, Simone Marzioni (University of Bologna)
 Spectral Action on $SU(2)$, Alan Lai (Caltech)
- Jun** Physical Principles Underlying the Fractional Quantum Hall Effect, Jürg Fröhlich (ETH Zürich)
 Nielsen Lecture: The Problem of Dynamics in Quantum Theory, Jürg Fröhlich (ETH Zürich)
 Centre Day seminar talk (QGM), Maxim Kontsevich (Institutes des Hautes Études Scientifique (IHÉS))
 G-Higgs bundles and mirror symmetry, Nigel Hitchin (University of Oxford)
 On quantum field theories for space times with boundary, Nicolai Reshetikhin (UC Berkeley)
 Cluster varieties from Thurston diagrams, Vladimir Fock (Strasbourg)
 QGM PhD Retreat 10 - 14 June
 Inverse spectral theory and the Minkowski problem for the surface of revolution, Evgeny Korotyaev (Saint Petersburg State Uni.)
- Jul** Nielsen Lecture, On the pseudonorm project towards birational classification of algebraic varieties, Shing-Tung Yau (Harvard Uni.)
- Aug** Lambda: The ultimate syntax-semantics interface, Chung-chieh (Ken) Shan (Indiana University)
- Sep** Lusztig's conjecture on modular irreducible characters fails for small and not so small primes I, Henning Haahr Andersen (QGM)
 Lusztig's conjecture on modular irreducible characters fails for small and not so small primes II, Henning Haahr Andersen (QGM)
 Descent Data and Braid group actions on categories, Sergey Arkhipov (Aarhus University)
 Derived Reid's recipe for abelian subgroups of $SL^3\mathbb{C}$, Timothy Logvinenko (Cardiff University)
 Geometry, topology and algebra of configuration spaces, Florian Schätz (QGM)
 On the geometry of moduli spaces of vector bundles, Peter Zograf (Steklov Institute, St.Petersburg)
- Oct** sl_3 -web bases and categorification, Daniel Tubbenhauer (Mathematisches Institut, Göttingen)
 Khovanov homology and the symmetry group of a knot, Liam Watson (University of Glasgow)
 Bogomolny monopoles and the existence of representations, Kim Frøyshov (QGM)
 Gluing equations and double covers, Roland van der Veen (University of Amsterdam)
 Bases for Integral TQFT lattices, part II, Gregor Masbaum (Institut de mathématiques de Jussieu)
 Combinatorics of Deformation Quantization on Kähler Manifolds, Niels Leth Gammelgaard (QGM)
- Nov** On higher dimensional analogues of braid representations, Camilo Arias Abad (Max Planck Institute)
 sl_3 -web bases, categorification and invariants of links Daniel Tubbenhauer (QGM)
- Dec** Joint iBMath and QGM workshop
 Graphical calculus for $gl(1|1)$ -representations and their categorification, Antonio Sartori (University Bonn)
 Quiver embeddings for Mori Dream Spaces, Alastair Craw (University of Bath)

PHD INTERACTION

The population of QGM PhD students is spread across three institutions: Aarhus, Oxford and UC Berkeley. Stimulating a fruitful and coherent research environment for our junior researchers is absolutely pivotal, and QGM continually encourages and initiates events which will bring together our PhD students.

Retreat for PhD Students from Aarhus, Oxford and Berkeley

10-14 June 2013, 4 of the Centre's PhD students from Oxford and Berkeley visited QGM for the annual PhD retreat. The main purpose with the retreats is networking, so all participating PhD students who have their master's degree are invited to give a talk. The workshop thus offers an excellent opportunity for QGM junior researchers across their respective home institutions to present their work to each other, exchange ideas, offer feedback and network with peers.

An exciting program

The PhD retreat this year was intentionally scheduled in the same week as the DNRF's site visit (see below) took place with the aim of organising an exciting program for the students. Professor Nigel Hitchin, Maxim Kontsevich and Nicolai Reshetikhin was among others speakers at the highly attractive program. Further the PhD program consisted of a series of talks by the PhD students to fellow PhD students, followed by discussions.



FIVE MORE YEARS FOR QGM

The Danish National Research Foundation (DNRF) conducts a mid-term evaluation of each Center of Excellence after three years. QGM was asked to submit a self-evaluation and an application for a second funding period. An international review panel evaluated the center, and the review process included a site visit to the center by the panel which lead to the international expert panel to conclude:

In a short period of time the QGM has established itself as the premiere center for research in the area of moduli spaces and quantization. The importance of this subject is reflected in the high level of activity by internationally recognized mathematicians. This core focus has found surprising applications to the structure of macromolecules and protein folding. While a great deal of progress has been made on the research goals outlined in the initial project, new avenues of investigation have been revealed. Further progress on the projects outlined in the new research proposal will certainly have significant ramifications in pure mathematics, mathematical physics, combinatorics and computation, and mathematical biology.

The presence of the QGM has dramatically enhanced the importance of Aarhus as an international center of mathematical research. The center has also maintained a commitment to graduate education and a postdoctoral program that will train the next generation of researchers in this field. The management plan of QGM is sound and efficient, and its Director has been extremely effective in generating activity and exploiting new opportunities as they arise.

INTERNATIONAL ASSOCIATE PARTNERS

QGM's scientific standing is underlined by the caliber of the internationally esteemed institutions which have formed collaborative partnerships with the Centre:

University of Oxford, UK

Professors Nigel Hitchin, Alexander Ritter and Dominic Joyce

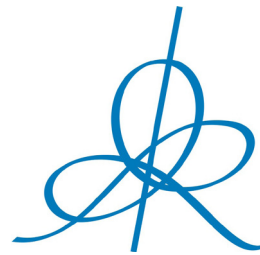


Institut des Hautes Études Scientifiques (IHÉS), France

Professors Maxim Kontsevich and Robert Penner

University of California Berkeley, US

Professors Nicolai Reshetikhin, Edward Frenkel and Denis Auroux



California Institute of Technology (Caltech)

Professors Hiroshi Ooguri, Sergei Gukov, Anton Kapustin & Robert Penner

Collaboration with China

QGM and the Mathematical Sciences Center at Tsinghua University, China are now official collaborating partner institutions. The agreement is a collaborative research agreement, which involves exchanges of both junior and senior researchers as well as joint events.



Jørgen E. Andersen signing a collaborative agreement with Professor Shing-Tung Yau, Tsinghua University.

Tata Institute of Fundamental Research



Chennai Mathematical Institute



Collaboration with India

QGM began a formal collaboration with Tata Institute of Fundamental Research (TIFR project leader Nitin Nitsure) and Chennai Mathematical Institute (CMI project leader Vikraman Balaji) in 2013 after a DKK 4 mill extra grant was awarded to QGM from DNRF in dec 2012.

In March 2014 fifteen QGM researchers visited the CMI and TIFR for one month. During this period also a joint conference was held at Kerala School of Mathematics.

In June 2014 we welcome our Indian partners in DK, as three world-class scholars from CMI and TIFR are giving a masterclass at QGM: Nitin Nitsure, Indranil Biswas & Vikraman Balaji.

EMS/DMF Joint Mathematical Weekend

In celebration of the Danish Mathematical Society (DMF)'s 140 years anniversary, DMF jointly with the European Mathematical Society (EMS) invited mathematicians from all over Europe to an EMS/DMF Joint Mathematical Weekend 5-7 April 2013. The weekend offered plenary talks and parallel sessions with invited speakers as well as a poster session where all participants (especially junior researchers) was invited to submit a poster for presentation.

Scientific Committee

Jørgen Ellegaard Andersen (QGM, Aarhus University)
 Jeremy Gray (Open University)
 Jesper Grodal (Copenhagen University)
 Laurence Halpern (University Paris 13)
 Vagn Lundsgaard Hansen (Technical University of Denmark)
 Martin Raussen (Aalborg University)
 Bjarne Toft (University of Southern Denmark)

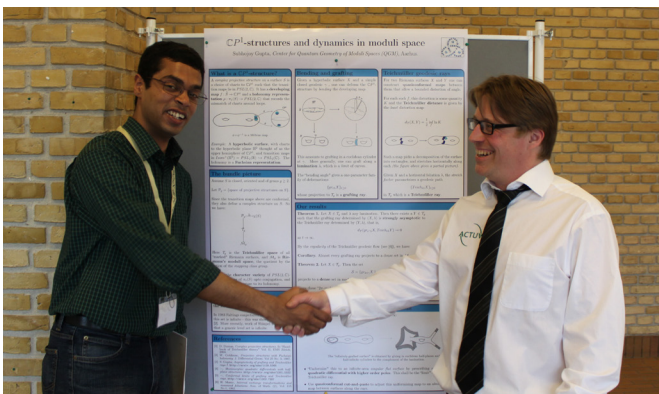
Plenary speakers

Henri Berestycki, CAMS at EHESS, France
 Herbert Edelsbrunner, IST, Austria
 Jeremy Gray, The Open University, UK
 Uffe Haagerup, University of Copenhagen, DK
 Carsten Thomassen, Technical University of Denmark

There were 8 parallel sessions with many very interesting talks. The 34 talks in total covered the whole spectrum of mathematics.

Concurrently with this event the presidents of the national mathematical societies in Europe held their annual meeting in Aarhus. Administrative Manager of QGM, Jane Jamshidi, was in the local organising committee of both events. It was a great pleasure to be able to assist the Danish Mathematical Society to arrange their 140th anniversary.

QGM postdoc won the poster award



QGM participated with three posters, and one of these was selected as the winner: QGM postdoc, Subhojoy Gupta, won the poster award of 2000 DKK at the EMS/DMF Joint Mathematical Weekend 5-7 April 2013 at Aarhus University.

Meeting of Presidents 2013



Participants at the Meeting of Presidents 2013
 QGM was local organiser of the events.

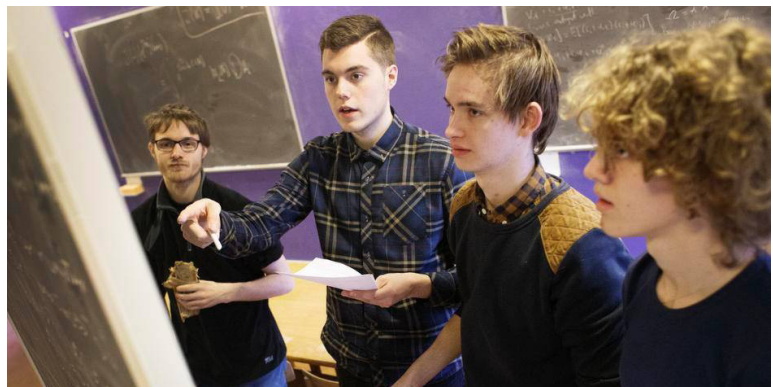
QGM MATH CLUB

For the third time QGM arranged Math Club; a weekend for upper secondary school students to get a hint of mathematics at university level, and this year the event reached the highest number of participants. 25-26 Jan 2014 a total of 50 high school students from all over Denmark came to participate in the annual QGM Math Club.

Math Club aims to inspire some of the brightest to choose a carrier in research. The teachers, who are PhD students at QGM, uses the event to pass on their passion for mathematics to young people facing the choice of what to do when they leave school. The academic level of the Math Club course is higher than the teenagers are used to at upper secondary school, and the pupils enjoyed the challenge of attending lectures as well as dealing with different mathematical exercises.

Media features

Jyllands-posten.dk, 27.01.2014
 JP Aarhus, 27.01.2014
 Aarhus Stiftstidende, 26.01.2014
 Stiften.dk, 25.01.2014
 Tv2oj.dk, 25.01.2014
 Herning Folkeblad, 24.01.2014
 Scitech.au.dk, 24.01.2014
 Nordjyske Stiftstidende, 20.01.2014



IMAGINARY - through the eyes of mathematics

This interactive travelling exhibition was originally created at the Mathematical Research Institute of Oberwolfach in Germany. IMAGINARY has visited more than sixty towns and cities in fifteen countries since it first opened in connection with the Year of Mathematics 2008 in Germany.

QGM arranged in collaboration with the Danish Mathematical Society (DMF) and the Technical University of Denmark (DTU) for the exhibition to come to Denmark on the occasion of the DMF's 140th anniversary.

The exhibition included mathematical illustrations, visual interactive installations, 3D objects and their theoretical background.

The IMAGINARY science and art exhibition was displayed at the Steno Museum in Aarhus from April to the end of August 2013.



Picture of laser-in-glas-cubes from the exhibit 'IMAGINARY' at the Steno Museum, April-Aug 2013

QGM RESEARCH REPORTS

My main research interest is categorification of quantum groups and its applications in representation theory, low dimensional topology and algebraic geometry. In particular, I am interested in algebraic, combinatorial and diagrammatic aspects of categorification. I am also interested in highly related topics like representation theoretic questions about Hecke algebras or Lie groups and modular representation theory. Let me get more precise what I am doing at the moment.

Daniel Tubbenhauer
Postdoc at QGM



It is known for quite some time that the so-called sl_n -link polynomials can be obtained using the representation theory of the quantum groups $U_q(sl_n)$. This follows from work pioneered by Reshetikhin and Turaev at the beginning of the 90ties. As a special case, using only the fundamental representation of $U_q(sl_2)$, their construction “explains” the celebrated Jones polynomial as an intertwiner of $U_q(sl_2)$ -representations.

Again, the categorified quantum groups have turned out to be more interesting than the quantum groups itself: They are isomorphic to certain Grothendieck groups of these categorifications.

In 1999 Khovanov started a “new generation” of link invariants by introducing what is nowadays called *Khovanov homology*. It categorifies the Jones polynomial in the sense that its graded Euler characteristic gives the Jones polynomial. Shortly after his breakthrough his constructions where extended to categorifications of the sl_n -link polynomials called the sl_n -link homologies (by various authors using different approaches). This has turned out to be powerful and more interesting than the sl_n -link polynomials: It contains them as special cases.

Thus, a natural question is if we can obtain the sl_n -link homologies using “higher” representation theory of $\check{U}_q(sl_n)$. My main ingredient is *categorified q -skew Howe duality* recently studied by various authors.

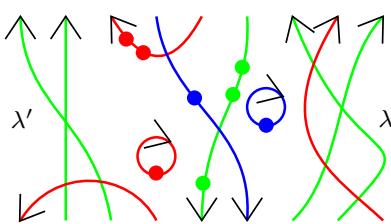
Using this I study how categorified $\check{U}_q(sl_m)$ -highest weight theory (the m is not a typo!) can be used to obtain the sl_n -link homologies. Roughly, it “explains” the sl_n -link homologies as complexes as for example:

$$\begin{array}{ccc}
 & F_t F_4 F_3 F_2 F_3 F_b v_h \{5\} & \\
 \tilde{\Gamma}(\times): F_3 F_4 \rightarrow F_4 F_3 & \uparrow & \tilde{\Gamma}(\times): F_2 F_3 \rightarrow F_3 F_2 \\
 F_t F_3 F_4 F_2 F_3 F_b v_h \{4\} & \oplus & F_t F_3 F_4 F_2 F_3 F_b v_h \{6\} \\
 \tilde{\Gamma}(\times): F_2 F_3 \rightarrow F_2 F_3 & & -\tilde{\Gamma}(\times): F_3 F_4 \rightarrow F_4 F_3 \\
 & F_t F_4 F_3 F_2 F_3 F_b v_h \{5\} &
 \end{array}$$

Moreover, around 2008, Khovanov and Lauda introduced $U(sl_n)$ which categorifies $\check{U}_q(sl_n)$ (an idempotent completion of $U_q(sl_n)$ that is easier to work with but the “same”) and Khovanov-Lauda and independently Rouquier introduced the so-called *cyclotomic KL-R algebra* that categorifies the highest weight representations of $\check{U}_q(sl_n)$. Khovanov and Lauda’s approach consists of a beautiful graphical calculus of what we call string diagrams and relations as for example:

using the cyclotomic KL-R algebra (the \times is an elements of the cyclotomic KL-R algebra). Here the F ’s act as elements of $\check{U}_q(sl_m)$ on a certain highest weight vector v_h . To explore the consequences of this construction is one of my next goals.

So let us see what the future brings!



and

$$\lambda + \alpha_i \begin{array}{c} \text{U-shape} \\ \downarrow \\ \lambda \end{array} = \lambda + \alpha_i \begin{array}{c} \text{Y-junction} \\ \downarrow \\ \lambda \end{array} = \lambda + \alpha_i \begin{array}{c} \text{U-shape} \\ \downarrow \\ \lambda \end{array}$$

Florian Schätz

Postdoc at QGM



The concept of holonomy is of central importance to the modern understanding of geometry and physics. It provides a link between local information on the one hand and global information on the other. For instance, the shift in the phase of an electron, which is moving within an electromagnetic field, is determined by the holonomy of the gauge potential along the path traced out by the particle.

With the advent of physical theories in which the fundamental entities are not particles, but more complicated objects such as strings, and the emergence of the corresponding mathematical structures, the importance of a higher dimensional version of parallel transport became apparent.

Several ways of generalizing ordinary parallel transport are known. Among these, gerbes and various notions of their 2-holonomies form the most prominent group. Another interesting generalization is provided by the concept of "homotopy quantum field theories" (HQFTs). These theories are close relatives of topological quantum field theories, but with maps to a fixed target space added.

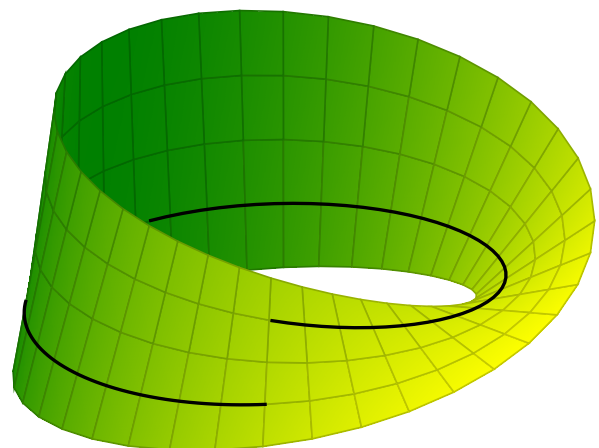
Together with Camilo Arias Abad (now Max-Planck Institute in Bonn), I am working on yet another generalization, the theory of higher holonomies for flat superconnections. These holonomies were originally constructed by Kiyoshi Igusa, who used them to study higher torsion classes of fibre bundles. Relying on Chen's iterated integrals, one associates holonomies not only to paths, but to arbitrary simplices inside a manifold M . In higher-category-speak, these higher holonomies assemble into a representation of the ∞ -groupoid $\pi_\infty(M)$ of M . An advantage of this approach is that it allows one to define holonomies for simplices of arbitrary dimension in a consistent manner.

Camilo Arias Abad and I extended this approach to flat connections with values in L_∞ -algebras. These algebras are the natural replacements of Lie algebras in the world of homotopy theory. In fact, flat connections with values in these coefficient systems allow one to make contact with the theory of rational homotopy theory.

Using this connection (no pun intended!), we were able to generalize the Drinfeld-Kohno construction of braid group representations to configuration spaces of points in higher dimensional Euclidean space. These findings recently appeared in *Homotopy, Homology Appl.* Vol 16 (2014), Nr. 1, 89-118.

Another joint project aimed at relating the higher holonomies of a flat superconnection to the 2-holonomies of a flat gerbe as defined by Baez-Schreiber, Schreiber-Waldorf and Martins-Picken. This project recently resulted in a preprint and opens up the possibility to exchange ideas between the two approaches.

In particular, there are hints from the theory of gerbes that it is possible to construct HQFTs, which were mentioned above, from flat superconnections. For instance, Bunke, Turner and Willerton showed that flat gerbes of rank 1 are in bijection with 2-dimensional HQFTs of rank 1. It would be interesting to translate this result into the language of flat superconnections, and to extend it to the non-abelian, as well as to the higher-dimensional, setting.



Picture illustrating holonomy of the Möbius-strip

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Theo Johnson-Freyd, UC Berkeley: Perturbative Methods in Path Integration

Laura Schaposnik, University of Oxford: Spectral data for G-Higgs bundles

Dan Berwick-Evans, UC Berkeley: Supersymmetric sigma models, partition functions, and the Chern-Gauss-Bonnet Theorem

Qualifying dissertations

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Kanstrup, T., Demazure descent theory (Aarhus University)

Masulli, P., Deformation quantization and trivialization of the formal Hitchin connection (Aarhus University)

Pedersen, D.H., Twisting functors for Quantum Group Modules (Aarhus University)

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Preprints

In 2013 QGM employees and associates produced 36 preprints. (For further information, please see: <http://qgm.au.dk/statem/pub/>)

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Arkhipov S. & Kanstrup, T., Demazure descent and representations of reductive groups (Aarhus University)

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