Centre for Symmetry and Deformation

Department of Mathematical Sciences, University of Copenhagen

ANNUAL REPORT 2011

(1 Jan - 31 Dec, 2011, "Year 2")
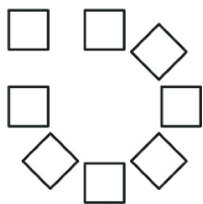
DNRF Centre for Symmetry and Deformation (SYM)
Department of Mathematical Sciences
University of Copenhagen

Established 1 Jan, 2010

CONTENTS

Centre for Symmetry and Deformation
Department of Mathematical Sciences, University of Copenhagen

CENTER HIGHLIGHTS 2011

The year 2011, the second year in the center's existence, featured exciting research breakthroughs, several large conferences centered around our visiting professors, and an expansion and consolidation of the center's PhD and MS programs.

ACTIVITIES

The center hosted 5 masterclasses and 4 conferences in 2011. Our distingushed visiting professor in the spring Bob Oliver (Univ. Paris 13) was the focal point of a range of activities, culminating in a very successful workshop on the generalized Martino-Priddy conjecture, which had spectacularly been solved by Chermak and Oliver a few months earlier. In the fall, Eberhard Kirchberg (Humboldt-Univ. Berlin) was in residence, and a large conference was held in honor of his 65th birthday, with the participation of the main names in the field.

RESEARCH

An exciting development in 2011 was the proof by Chermak and Oliver, already mentioned. Within the same area, an earlier paper by Broto-Møller-Oliver was accepted to *J. Amer. Math. Soc.*, adding to our track record of leading publications. Guided by 2010 results, Berglund-Madsen and Galatius-Randal Williams gave two different homological stability theorems, going far beyond the classical Harer stabillity theorem in 2 dimensions. In noncommutative geometry, the PhD students at the center proved several groundbreaking results, in particular on C*-algebras of real rank zero. Special mention is also reserved for Haagerup-de Laat's broad determination of groups without the approximation property, vastly extending an example of Lafforgue-de la Salle. Our research was internationally resoundingly recognized through Ib Madsen winning the prestigious Ostrowski prize 2011.
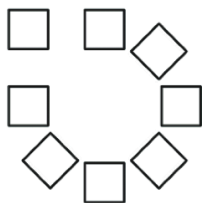
EDUCATION AND OUTREACH

With the large influx of PhD students, sustained effort has been put into designing a research-level course program, as well as expanding and coordinating the MS program to better attract and prepare potential PhD students. Furthermore the center entered as main sponsor and contributor to the *Ungdommens Naturvidenskabelige Forening* MathCamp for high school students to be held at Univ. Copenhagen in summer 2012, and is heavily involved in the high school program *Math en Jeans*, including hosting teacher's training workshops. Our educational commitment was recognized by Søren Eilers winning the 2011 KU Faculty of Science Teacher of the Year Award.

Please visit *sym.math.ku.dk* for more information.

Centre for Symmetry and Deformation
Department of Mathematical Sciences, University of Copenhagen

CENTERHØJDEPUNKTER 2011

Året 2011, centrets andet år, bød på flere opsigtsvækkende forskningsgennembrud, store konferencer centreret omkring vores gæsteprofessorer, og en udvidelse og konsolidering af centrets ph.d.- og kandidatprogrammer.

AKTIVITETER

Centret var vært for 5 masterclasses og 4 konferencer i 2011. Vores gæsteprofessor i foråret, Bob Oliver fra Univ. Paris 13, var centrum for en række aktiviter som kulminerede i en successrig workshop om den generaliserede Martino-Priddy-formodning, som på spektakulær vis var blevet løst af Chermak og Oliver blot få måneder forinden. I efteråret var Eberhard Kirchberg fra Humboldt Universitet Berlin vores gæst, og der blev afholdt en stor konference til ære for hans 65-årsfødselsdag, med deltagelse af alle hovedpersonerne inden for hans forskningsfelt.

FORSKNING

En vigtig begivenhed i 2011 var det allerede nævnte bevis af Chermak og Oliver. Inden for samme forskningsområde blev en tidligere artikel af Broto-Møller-Oliver optaget i *J. Amer. Math. Soc.*, visende vores fortsatte forskningsmæssige gennemslagskraft. Ledt af resultater fra 2010 beviste Berglund-Madsen og Galatius-Randal-Williams to forskellige homologiske stabilitetssætninger som tilsammen kan ses som langtrækkende generaliseringer af Harers klassiske stabilitetssætning i 2 dimensioner. I ikke-kommutativ geometri producerede centrets ph.d.-studerende flere banebrydende resultater, specielt omkring C*-algebraer af reel rang nul. Ligeledes fremstår Haagerup og de Laats bestemmelse af en lang række grupper uden approksimationsegenskaben som et højdepunkt. Vores forskning modtog i 2011 stor international anerkendelse i form af tildelingen af Ostrowski-prisen til Ib Madsen.

UDDANNELSE OG FORMIDLING

Som følge af den kraftige vækst i antallet af ph.d.-studerende er der blevet udviklet et kursusprogram på forskningsniveau. For bedre at kunne forberede potentielle ph.d.-studerende, er kandidatprogrammet blevet udvidet og forbedret. Ligeledes er centret gået ind som hovedsponsor og bidragsyder til *Ungdommens Naturvidenskabelige Forenings* MathCamp for gymnasieelever, og centret er kraftigt involveret i gymnasieprogrammet *Math en Jeans*, hvor vi blandt andet står for workshops med gymnasielærere. Vores indsats på undervisningsområdet er ikke gået ubemærket hen, idet Søren Eilers blev udnævnt til Årets Underviser på Det Naturvidenskabelige Fakultet, KU, 2011.
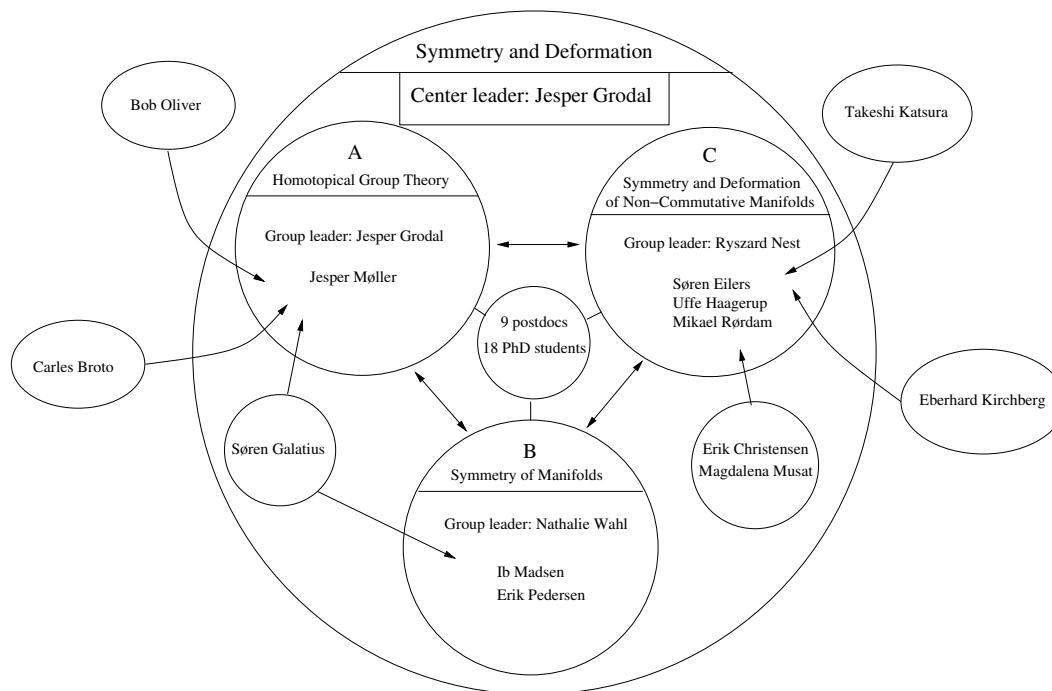
Besøg vores hjemmeside *sym.math.ku.dk* for mere information.

2. Organization

Below is an updated diagram of the center's *scientific structure*, based on the appendix staff list:

The composition of the *scientific staff* has been adjusted in the following ways since the last annual report:

- A. Berglund was promoted from postdoc to assistant professor per 1/8/2011.
- Ult. 2011 the number of postdocs/assist. prof was 9 (ult. 2010: 13; contract: 6).
- Ult. 2011 the number of PhD students was 18 (ult. 2010: 16; contract: 6).

Seven PhD students (D. Egas, C. Guldberg, M.W. Jacobsen, S. Knudby, M. Lopez, S. Reeh, and K. Moi) were hired during 2011 to the 3-year PhD program. Five PhD students (S. Arklint, T. Bargheer, C. Esposito, R. Johansen, and G. Napolitano) finished their studies. Currently, 12/19 of our PhD students and 9/9 of our postdocs are non-Danes. In 2011 we set up procedures for students to enroll in a 1-year MS program before the 3-year PhD program, to be better compatible with US and UK undergraduate institutions.

Two postdocs, S. Deprez and J. Kuit, were hired in 2011, and six left the center: S. Basu, R. Hepworth, L. Roberts got permanent jobs at Vivekananda (India), U. Aberdeen, and U. Louisiana respectively, and C. Levy, T. Shulman, and O. Uuye went on to postdoc positions at U. Potsdam, Siena College (US), and U. Cardiff respectively. We pride ourselves in the success of our postdocs in securing high-level continued academic employment. Postdocs accepting permanent positions elsewhere late in the hiring season however caused their number in fall of 2011 to be around 2 lower than planned, since high caliber replacements were not readily available.

We had two main distinguished visiting professors, B. Oliver in the spring and E. Kirchberg in the fall. Additional long-term visitors included professors K. Andersen (6 mth), C. Broto (5 mth), T. Carlsen (3 mth), L. Hesselholt (1 mth), T. Katsura (8 mth), H. Miller

(1 mth), and A. Ruiz (3 mth). We also had 3 visiting PhD students, and our guest data-base on `sym.math.ku.dk` lists 130 short-term visitors to the center in 2011.

In terms of *administrative structure*, S. Arklint started as center administrator on 1 Jan, 2011, in a half-time position concurrent with her PhD studies at the center. She was on leave 1 July - 31 Dec, 2011 to finish her PhD studies, during which time the center was without a regular administrator. Thereafter S. Arklint has restarted as center administrator, in a full time position which allows her to spend roughly 50% of her time on research or teaching. We continue to acquire 5hrs/week of assistance from N. Guld-dal, Nørre Campus Institutadministration (NCI), to deal with budgetary and accounting matters not covered by NCI's ordinary accounting function.

3. Research plan

We here provide an update on our research, which is structured under three head-ings *(A) Homotopical group theory, (B) Symmetry of manifolds*, and *(C) Symmetry and deformation of non-commutative manifolds*, with 3 research goals each.

(A) Homotopical group theory

> **Core:** J. Grodal, J. M. Møller.
> **Associated:** K. Andersen, C. Broto (visiting), H. Miller (visiting), B. Oliver (visit-ing), A. Ruiz (visiting).
> **Postdoc:** M. Gelvin, E. Henke.
> **PhD:** M. Jacobsen (JMM), T. Nørgård-Sørensen (JG), S. Reeh (JG).

(A1) *p–local finite groups and their relationship to group and representation theory.* There was much activity in this area during 2011, centered around the visit by Bob Oliver in the spring, and much progress was made. We mention some highlights: A. Chermak and B. Oliver solved the generalized Martino–Priddy conjecture, a major breakthrough for our research. Furthermore Broto–Møller–Oliver continued their progress in understanding the p–local structure in finite groups of Lie type, extending the results in their JAMS paper, which appeared early 2012. J. Grodal identified the Burnside ring of the p–completed classifying space of a finite group with Burnside ring of the corresponding p–fusion system, hence providing an "uncompleted" version of the Segal conjecture. And, E. Henke has made progress on the large Aschbacher program of classifying all simple 2-fusion systems, by giving results towards a classification of minimal non-solvable fusion systems.

(A2) *Classification of group actions on finite complexes.* In 2011, there was a summer program in this area, centered around the workshop and masterclass "Homotopical ap-proaches to group actions". A. Adem, I. Hambleton, J. Smith, and P. Symonds visited for longer periods of time, and gave lectures. There was progress in many directions, and extensions of previous work. But the perhaps most spectacular outcome of that program came much later, in early 2012, where Benson–Grodal–Henke managed to solve a prob-lem raised by P. Symonds at the problem session there, namely the relationship between isomorphism and F–isomorphism in group cohomology, with tools involving a mixture of A1 and A2—we will be reporting on this in more detail next year.

(A3) *The homotopy theory of loop groups and affine p–compact groups.* T. Nørgård-Sørensen has been studying the representation ring of p–compact groups and obtained a complete description for several p–compact groups of low rank. In the cases verified he gets an intriguing analog of the classical formula as Weyl group invariant sums of

weights of the maximal torus, and we are pursuing this relationship. Our 2011 postdoc application process identified several strong researchers with detailed algebraic knowledge of Kac-Moody groups who will arrive at the center in fall 2012.

(B) Symmetry of manifolds and moduli spaces

Core: I. Madsen, E. K. Pedersen, N. Wahl.
Associated: L. Hesselholt (visiting).
Postdoc: S. Basu, A. Berglund, R. Hepworth, H. Gimperlein, A. Lahtinen, O. Randal-Williams.
PhD: T. Bargheer (NW), T. Danielsen (ext), E. Dotto (IM), C. Guldberg (NW), A. Klamt (NW), M. Lopez (EKP), K. Moi (IM), G. Napolitano (ext).

(B1) *Symmetry of Riemann surfaces.* Further progress was made on several aspects of this point on the research plan. Wahl–Westerland produced the first of a series of papers on natural operations on the Hochschild complex of structured algebras. Their general theory unifies work of a number of authors on topological conformal field theories, and leads to a proof of universality of spaces of operations. Hepworth–Lathinen have made significant progress in their ongoing work on field theories associated to classifying spaces; they generalize the work of Chataur–Menichi to a full open-closed theory, and show that the operations are naturally parametrized by "homotopy-graphs", rather than by the expected surfaces or fat-graphs. The year ended with a very inspiring master class by C. Faber and O. Randal-Williams on the tautological ring, which we hope will bear its fruits in the near future.

(B2) *Symmetry of 3–manifolds.* The goal of this part of the research plan is to extend the machinery used to study symmetries of surfaces to the study of symmetries of higher dimensional manifolds, in particular those of dimension 3. There was an emphasis on this part of the research plan during the academic year 2010/11, and much progress was made. Building on the progress described in our 2010 report, the results were extended from different angles by two homological stability theorems: A theorem by Galatius–Randal-Williams using the Madsen–Weiss theorem and "classical" homological stability techniques, and a theorem by Berglund–Madsen using a combination of surgery theory and rational homotopy theory. This latter work relies on more general work of Berglund on Koszul spaces and new methods for studying mapping spaces. The work of these four authors taken together represents significant progress on understanding symmetries of high-dimensional manifolds, using methods which mix very classic and brand new techniques from different areas of algebraic topology.

(B3) *Algebraic K–theory and classification of manifolds.* Hesselholt and Madsen are developing the theory of Real algebraic K–theory, and K–theory with extra structure. This is a substantial project, where aspects are also currently being worked on by E. Dotto and K. Moi. This part of the research plan will be emphasized in 2012, where Hesselholt will be visiting for 6 months. Of further developments, Böckstedt-Madsen, in a preprint posted in 2011, relate categories of embedded manifolds to Waldhausen K–theory; this is a step in the generalized goal of B3, namely that relating the study of higher dimensional manifolds, to different versions of K–theory.

(C) Symmetry and deformation of non–commutative manifolds

Core: S. Eilers, U. Haagerup, R. Nest, M. Rørdam.
Associated: E. Christensen, T. Katsura (visiting), M. Musat.
Postdoc: C. Levy, J. Öinert, E. Ortega, O. Uuye, L. Robert, T. Shulman.
PhD: S. Anevski (RN), S. Arklint (SE), R. Bentmann (SE/RN), C. Esposito (RN), R. Johansen (SE), S. Knudby (UH), T. de Laat (MM/UH), H. D. Petersen (RN), M. Ramirez-Solano (EC), A. Sørensen (SE), H. Thiel (MR).

(C1) *Baum–Connes conjecture.* The answer to many questions around the Baum-Connes conjecture are expected to rely on a deeper understanding of both analytic and geometric properties of discrete groups with property T. In this direction, Haagerup and de Laat proved a very general result, that a large class of simple Lie groups do not have the weak approximation property, vastly extending an example of Lafforgue and de la Salle. H. D. Petersen has defined L^2–Betti numbers for locally compact groups, with applications to the metric structure and the computation of the L^2–Betti numbers of their sub-lattices, which include important classes of the discrete groups. Furthermore, O. Uuye extended a classical result of McClure about detection on subgroups in equivariant K–theory to equivariant KK–theory.

(C2) *Deformation quantization and index theorems.* S. Anevski gave a procedure for reconstructing the underlying topological space of a scheme from the tensor triangulated structure on its category of perfect complexes. She moreover gave analogous reconstruction results for monoid schemes, replacing perfect complexes by the finite stable homotopy category. This is an important step towards understanding the Riemann–Roch theorem in the context of Arakelov geometry, and its generalization to the theory of monoid schemes. C. Esposito has made important contributions towards a quantization of momentum maps for Poisson actions of Poisson Lie groups; in particular she gave the first example of a quantum momentum map for actions of Drinfeld–Jimbo quantum groups. R. Nest with collaborators has proved an index theorem for twisted cocycles arising from KMS states of C^*–algebras.

(C3) *Classification of C*–algebras.* During 2011 we have consolidated the general classification theory for non-simple C*-algebras: S. Arklint and R. Bentmann, in collaboration with our visitor T. Katsura, analyzed the nature of the Meyer–Nest invariant, resolving its effectivity completely in many key cases. They begin to see a connection with well-known algebraic structures such as Dynkin diagrams, arising as in Auslander–Reiten theory, which we hope will be developed in 2012. Simple graph C^*–algebras have been known to be classifiable for decades, but A. Sørensen showed in 2011 how to realize this classification, in the unital case, by "basic moves", as in knot theory, and hence turned the existing algebraic classification result into a geometric one. This is an important breakthrough, as the approach should generalize to the non-simple case, and classification results for non-simple graph C^*-algebras are expected in 2012. Finally we mention that L. Robert and M. Rørdam proved new interesting results on divisibility properties for C^*-algebras.

4. Commentary on the appendix

Overall the numbers indicate that the high standard set last year for research and activity continues, and we see a boost with respect to education and outreach.

Appendix—A: External relations. The table lists 70 external collaborators on journal articles, the vast majority international. We also mention that we in 2011 hosted 130 scientific guests at the center (where a guest is defined as someone who gets a building key and office space during their visit). We furthermore keep in regular contact with colleagues from major mathematics departments around Europe and USA to coordinate our researcher training activities.

Appendix—B: Conferences. (Ba) lists 9 events at the center in the form of 4 conferences/workshops and 5 masterclasses, plus 3 external events. The conference number is a bit lower than last year, which was exceptionally high due to inauguration and birthday activities, but it is still high. There is an increased number of masterclasses, which reflects our increased researcher training activities. (Bb) lists 55 invited talks spanning four continents.

Appendix—C: Educational activities. The table lists 10 graduate courses and states that we in 2011 produced 10 MS graduates and 13 BS graduates. Of the 10 MS students, 6 have gone on to pursue PhD degrees, 4 at the center. In particular the number of BS graduates is significantly higher than last year, which we ascribe to efforts adjusting the course program to more naturally lead into theses projects.
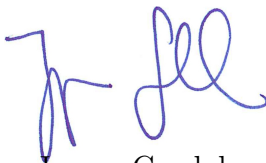
Appendix—D: External funding. Also in 2011 we received significantly more in external funding than stated in the contract, again mainly due to the 3 ERC grants, our EURYI grant, and the KU "Programme of Excellence" grant. We received a total of approx. 12 MDKK in external funding in 2011 and approx. 5.5 MDKK from DNRF.

Appendix—F: Public outreach. We draw attention to an increase in public outreach, in particular with respect to engaging high-school students.

Appendix—H: Publications. The 2011 publication list consists of 24 journal publications, 1 conference proceeding article, 1 book, and 1 book chapter. Three of the journal publications appear on the "top-10" list; the publication list also contains several other top publications, e.g., two articles in Commun. Math. Phys., a leading mathematical physics journal. 31 new preprints were added to our preprint series "CPH-SYM" on `www.arxiv.org`. We note that a publication is listed only if it has been actively worked on while the authors were employed, or for long-term visitors physically present, at the center. Overall the numbers are statistically unchanged from last year.

5. Signature

I hereby confirm the correctness of the information concerning annual accounts, including itemizations. Also, I confirm that the annual reporting, including the Appendix, is correct, i.e. it is free of material misstatement or omissions, and that the administration of the funds has been secure and sound, and in accordance with the conditions of the center agreement.

31 March, 2012   Jesper Grodal
                          Professor, Center Director