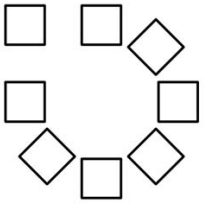

Centre for Symmetry and Deformation

Department of Mathematical Sciences, University of Copenhagen

Annual report 2016

(1 Jan - 31 Dec, 2016, "Year 7")

DNRF Centre for Symmetry and Deformation (SYM)

DNRF92

Department of Mathematical Sciences
University of Copenhagen

Established Jan 1, 2010

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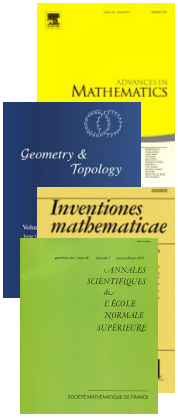
Centre for Symmetry and Deformation

Department of Mathematical Sciences, University of Copenhagen

CENTER HIGHLIGHTS 2016

The year 2016 saw the arrival of Søren Galatius and Dan Petersen as new permanent faculty, Galatius with a ERC Consolidator Grant in tow. New theorems, lectures around the world, and even an installation with cupcakes in a Sierpinski triangle, made for a memorable year.

ACTIVITIES. The center hosted 2 conferences, 2 masterclasses, and 162 individual visitors. The Uffe Haagerup memorial symposium in June for close friends and collaborators had a participant list that read like a who's who in the world of operator algebras. At the biannual *YTM* in July, keynote speakers Mathew, Randal-Williams, and Wahl lectured for 180 junior researchers. Activity outside UCPH was also high, with center members organizing 2 conferences, 5 workshops, and the spring program on operator algebras at Institute Mittag-Leffler. With a 104 invited talks around the world, including 7 research lecture series, such as the esteemed DeLong Lectures at Boulder by Musat, our research reached a large international audience.



RESEARCH. Several well-known conjectures turned to theorems: Grodal answered the Carlson–Thévenaz conjecture in the positive, by giving a simple homotopical description of the unknown part of the group of endo-trivial modules. And Szymik and Wahl answered a 25 years old question of Ken Brown in the positive by showing that Thompson's group V has no homology, a consequence of a more general calculation for Higman–Thompson groups. We had 6 papers accepted to our top-10 journals. The description of the spectrum of the equivariant stable homotopy category by Balmer–Sanders was accepted to the top-3 journal *Invent. Math.* The paper by Alm–Petersen highlighted last year went to *Ann. Sci. École Norm. Supér.*; two papers by Cantero–Randal-Williams and Petersen got accepted in *Geom. Top.* and two by Patchkoria and Degrijse in *Adv. Math.* Our overall output numbers were also solid, with 35 published papers and 45 additions to our preprint series CPH-SYM-DNRF92 on arXiv.org, with 9 postdocs and 14 PhD students at the center.

EDUCATION AND OUTREACH. We had a strong output of 13 MS graduates, with 4 continuing in PhD programs. Our dedication to teaching was extended to the BS program where we redesigned the first-year linear algebra course. We also embarked on the production of teaching material, in the form of a new linear algebra book and a textbook on experimental mathematics to be published by CUP. Our outreach activities also broke new ground with expository articles in the 530th issue of UCPH's traditional almanac and as a cover story in *Amer. Math. Monthly*.

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

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Centre for Symmetry and Deformation

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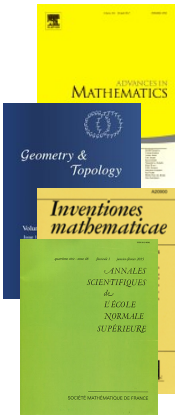
CENTERHØJDEPUNKTER 2016

Året 2016 så ankomsten af Søren Galatius og Dan Petersen som nye fastansatte, Galatius medbringende en ERC-consolidator bevilling. Nye sætninger, foredrag rundt omkring i verden og endda en installation med cupcakes i en Sierpinski-trekant skabte et mindeværdigt år.

AKTIVITETER. Centret var vært for 2 konferencer, 2 masterclasser og 162 individuelle gæster. Mindesymposiet for Uffe Haagerup i juni var for nære venner og samarbejdspartnere og havde en deltagerliste der lignede en blå bog for operatoralgebra. Ved det biennale *YTM* forelæste hovedtalere Mathew, Randal-Williams og Wahl for mere end 180 unge forskere. Aktivitetsniveauet uden for KU var også højt idet centermedlemmer arrangerede 2 konferencer, 5 workshops samt forårets program ved Institut Mittag-Leffler. Gennem 104 inviterede foredrag rundt omkring i verden, heriblandt 7 foredragsrækker såsom de prestigefyldte DeLong Lectures ved Boulder holdt af Musat, nåede vores forskning et stort internationalt publikum.

FORSKNING. Adskillige velkendte formodninger blev til sætninger: Grodal bekræftede Carlson–Thévenaz-formodningen ved at give en homotopisk beskrivelse af den ukendte del af gruppen af endotrivielle moduler. Og Szymik og Wahl gav et positivt svar på et 25 år gammelt spørgsmål fra Ken Brown ved at vise at Thompsons gruppe V ikke har homologi, en konsekvens af en mere generel beregning for Higman–Thompson-grupper. Vi fik 6 artikler accepteret i vores top 10-tidsskrifter. Balmer–Sanders' beskrivelse af spektret for den ækvivariante stabile homotopikategori blev accepteret i top 3-tidsskriftet *Invent. Math.* Artiklen af Alm–Petersen nævnt sidste år kom i *Ann. Sci. École Norm. Supér.*; to artikler af Cantero–Randal-Williams og Petersen blev accepteret til *Geom. Top.* og to af Patchkoria og Degrijse til *Adv. Math.* Vores generelle produktionstal var også solide, med 35 publicerede artikler og 45 tilføjelser til vores preprintserie CPH-SYM-DNRF92 på arXiv.org, med 9 postdocs og 14 ph.d.-studerende på centret.



UNDERVISNING OG FORMIDLING. Vi vejledte hele 13 specialestuderende hvoraf de 4 fortsatte som ph.d.-studerende. Vores stærke interesse for undervisning bredte sig til bachelordelen hvor vi redesignede førsteårskurset i lineær algebra. Vi gik også i kast med produktionen af undervisningsmateriale, både til lineær algebra og som en lærebog i eksperimentel matematik udgivet på Cambridge University Press. Vores repertoire af formidlingsaktiviteter blev udvidet med populærvidenskabelige artikler i den 530de udgave af KU's almanak samt som en forsidehistorie i *Amer. Math. Monthly*.

Besøg vores hjemmeside sym.math.ku.dk for mere information.

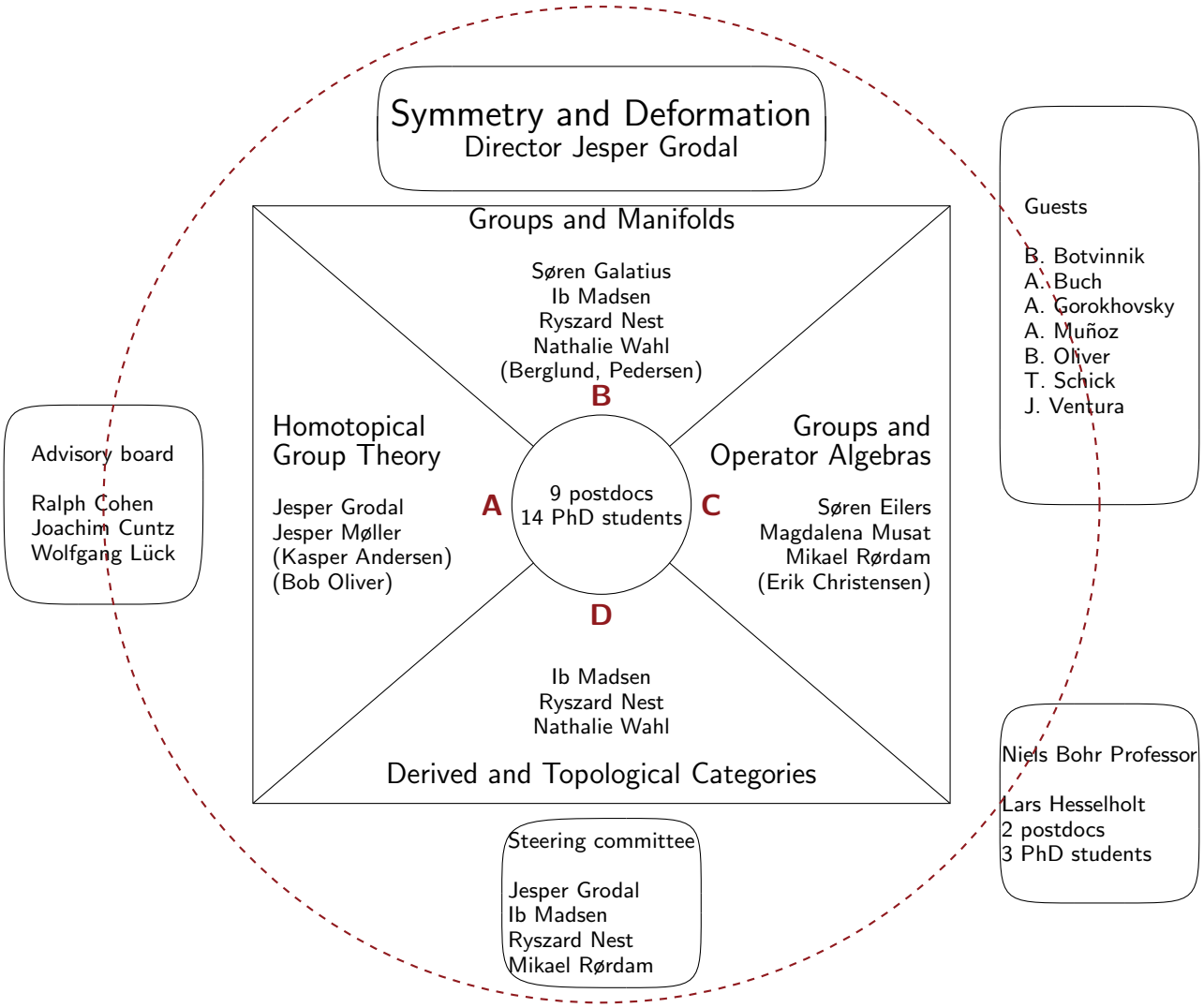
Finansieret af

Danmarks Grundforskningsfond

Danish National Research Foundation

2 Organization

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



2.1 Scientific staff

There was a big change in the senior academic staff this year with the hiring of Galatius as Professor and the promotion of Petersen to Associate Professor, and the retiring of Pedersen and Madsen. In terms of postdoc and PhD students, status looks as follows:

- Ultimo 2016 the number of postdocs/assist. prof was 9 (ult. 2015: 14; contract: 6).
- Ultimo 2016 the number of PhD students was 14 (ult. 2015: 14; contract: 9).

Three PhD students were hired during 2016, two of them (Brix, Jansen) to the 3-year PhD program, and one (Hunt) to the 4-year PhD program. Of the three PhD students who graduated (de Kleijn, Olesen, and Ungheretti), de Kleijn went to Université Libre de Bruxelles in a postdoc position, while Olesen and Ungheretti left academia for jobs in their home countries.

Three postdocs (Barthel, Hausmann, Kupers) were hired in 2016. Seven postdocs left the center: Degrijse and Yalin got assistant professorships at the National University of Ireland and Université Angers, Enders and Patchkoria got postdocs at Münster and Bonn, Wang at Fudan University in Shanghai, while Adamaszek and Rose left academia to work at Danish companies.

2.2 Visitors

We had 11 long-term visitors in 2016 (of which 5 were PhD students), visiting the center for a minimum of 3 weeks (16 in 2015, 15 in 2014, 32 in 2013, 21 in 2012), as well as 146 short-term guests (169 in 2015, 140 in 2014, 214 in 2013, 164 in 2012), some of these joint with Hesselholt's Bohr professorship. Notable long-term visitors in 2016 included our associated member Oliver, together with Buch and Ventura (visiting Grodal), Gorokhovsky (visiting Nest), and Schick (visiting Wahl). Furthermore, Muñoz visited as long-term visitor on an NSF GROW stipend.

2.3 Administration

The basic administrative structure within the center continued unchanged from last year, with hiring decisions being made collectively by the permanent members as described in previous reports, and with the interaction with the department following the guidelines set out in our business protocol created in 2012. The work of center administrator Arklint and student assistants continued along the same lines as described in previous reports. Arklint had 3.5 months leave in the spring. Ultimo 2016, Østergaard was replaced by Eilsøe-Madsen as center student assistant.

2.4 Recruitment and gender strategy

We steadly continue our push to obtain better gender balance, from previous years: Our PhD and postdoc recruitment is conducted through annual calls following international deadlines, with several hundreds of applicants, and candidates usually have competing offers from leading european and american universities. We pride ourselves in being more competitive every year, this year continuing that trend, with Kupers postponing an offer from Harvard, and Bartels turning down Univ. Chicago. We look at the file of female candidates extra carefully with point by point comparisons to the top male candidates, obtaining additional information in case of doubt. We did not manage to hire any female postdocs, but did hire one excellent female graduate student, who had done her MS thesis in Copenhagen with Clausen. In terms of senior faculty, the 9 permanent members constitute the search committee for the 4 embedment positions during the second period, with two already filled by Galatius and Petersen as mentioned. We expect the two remaining positions to be filled towards the end of the grant period, and of course hope that we can make female hires (to supplement Prof. Wahl and Assoc. Prof. Musat).

2.5 Research integrity

Let us repeat our philosophy and strategy from previous years: In mathematics it is hard to fake results, since proofs are included in papers for everyone to see. But there is the real possibility that errors or gaps go unnoticed, or slip through the refereeing process. Furthermore there can be the issue of plagiarization and failure to give proper credit to previous results, either willfully or through neglect. To minimize this we have chosen a publication strategy where we choose quality over quantity, aiming for high impact journals with thorough refereeing standards. We furthermore put all papers on the arXiv preprint server, as part of our report series CPH-SYM-DNRF92, before submission for publication, and discuss all papers at our monthly SYM meeting. We believe that research integrity should be viewed as part of a larger quest for integrity in all operations, and laud UCPH's efforts to set up an independent ombudsman function, though we again regret that the scope of this function is limited to students.

3 Research plan

We here report on specific progress on our 2015–2019 research plan, structured under the 4 headings **(A)** Homotopical group theory **(B)** Groups and manifolds **(C)** Groups and operator algebras and **(D)** Derived and topological categories.

(A) Homotopical group theory

Core: J. Grodal, J. M. Møller.
Visiting: A. Buch, B. Oliver, J. Ventura.
Postdocs: T. Barthel, M. Hausmann, B. Sanders, D. Sprehn.
PhDs: B. Böhme (JG), J. Hunt (JG), I. Laude (JG), T. Prytuła (JMM).

In a breakthrough result, Grodal showed that a range of methods from algebraic topology can be used to significantly advance a classical problem in modular representation theory, namely the classification of endo-trivial modules. He gave a computable formula for the last undescribed subgroup of the group of such modules, and showed how this unifies old results and leads to many new ones—further computational ramifications of this work are currently being worked on.

Møller completed his big memoir with Oliver and Broto on automorphisms of fusion systems of finite group of Lie type, a memoir that is expected to find applications in the classification program for fusion systems, and his student Prytuła constructed, together with Osajda, low-dimensional models for classifying spaces for families of subgroups for systolic groups. Sprehn and Lahtinen finished their work on modular characteristic classes for representations over finite fields, constructing the first family of non-trivial cohomology classes in degrees linear in the rank, and Sanders provided a very general viewpoint on classical duality statements in algebraic topology. The fall arrival of postdocs Barthel and Hausmann and PhD student Hunt, brought new blood to the area, setting up for progress in future years.

(B) Groups and manifolds

Core: S. Galatius, I. Madsen, R. Nest, D. Petersen, N. Wahl. (Associated: E. Pedersen.)
Postdocs: D. Degrijse, S. Kupers, G. Wang.
PhDs: M. Jansen (SG), M. Krannich (NW).

With their paper "Homological stability for moduli spaces of high dimensional manifolds. II" and building on their earlier work, Galatius and Randal-Williams computed in a range the homology of the moduli space of any simply-connected manifold of dimension $2n \geq 6$, providing a higher dimensional analogue of the Madsen-Weiss theorem that goes far beyond the hopes one may have had just 5 years ago. Szymik and Wahl pushed these ideas from manifolds to the world of Thompson groups: they showed that the Higman-Thompson groups satisfy homological stability, and identified their stable homology with that of the infinite loop space of a Moore spectrum. In particular, they showed that Thompson's group V has no homology, answering in the positive a 25 years old question of Ken Brown. Still in the realm of stability phenomena, Petersen introduced a new general method for studying the cohomology of configuration spaces and more general complements of discriminants, and used this to show that the phenomenon of representation stability holds for a far larger class of configuration-like spaces than earlier expected. And the work of Berglund and Madsen on diffeomorphisms and block diffeomorphisms of manifolds culminated in a 68 pages preprint entitled "Rational homotopy theory of automorphisms of manifolds". Using homological stability, Kupers showed that in dimensions not equal to 4, 5, or 7, the homology and homotopy groups of the classifying space of the topological group of diffeomorphisms of a disk fixing the boundary are finitely generated in each degree. Petersen gave a proof of a conjectured vanishing theorem for tautological classes on the moduli space of K3 surfaces. The surprisingly short proof (less than a page) will appear in *Am. J. Math.* Degrijse, together with Souto, constructed examples of groups with large geometric dimension compared to their virtual cohomological dimension.

(C) Groups and operator algebras

Core: S. Eilers, M. Musat, M. Rørdam. (Associated: E. Christensen.)
Visiting: A. Muñoz.
Postdocs: S. Arklint, C. Cave, O. Gabriel.
PhDs: K. Brix (SE), R. Bryder (MM), M. Christensen (MR), M. Andersen (MR), K. Olesen (MM/UH), E. Scarparo (MR).

During the spring, this area had much cross-over activity with the Mittag–Leffler Institute in Sweeden, where Eilers was a main organizer of the program "Classification of Operator Algebras: Complexity, rigidity and dynamics".

In Analytic and geometric group theory, and applications to operator algebras, Musat and Rørdam, with Grigorchuk, carried out a systematic study of just-infinite C^*–algebras, i.e., infinite dimensional C^*–algebras for which all proper quotiens are finite dimensional. They established a trichotomy theorem and examined when C^*–algebras of discrete groups are just-infinite. Graduating PhD student Olesen, joint with Haagerup, proved that the Thompson groups T and V are non-inner amenable, and made further progress on the notoriously difficult problem of deciding amenability of the Thompson group F, by relating it to whether the reduced group C^*–algebra of T is simple; this will appear in *JFA*. Bryder, currently in his final year, continued his study of reduced crossed products of unital C*-algebras by discrete groups in a paper in IMRN with Kennedy, and is currently looking into boundary actions as well as associated injective envelopes of such groups on compact Hausdorff spaces.

In Dynamical systems and symmetries of C^*–algebras, Eilers proved with several coauthors that flow equivalence of shifts of finite type is reflected exactly in the stable isomorphism class of the Cuntz–Krieger algebra, if one equips this with a diagonal subalgebra; this generalizes a result of Matsumoto and Matui from the irreducible to the general case.

(D) Derived and topological categories

Core: I. Madsen, R. Nest, N. Wahl.
Visiting: A. Gorokhovsky.
Postdocs: R. Haugseng, G. Heuts, I. Patchkoria.
PhDs: C. Canlubo (RN), N. de Kleijn (RN), E. Nielsen (NW), V. Proietti (RN), M. Ungheretti (NW).

Gorokhovski, de Klejin and Nest established the equivariant index theorem for actions of discrete groups on formal deformations of symplectic manifolds. de Kleijn defended his PhD thesis in September, where he also classified the extension of certain group actions on symplectic manifolds to their deformation quantization. Galatius and Venkatesh define a derived version of Mazur's Galois deformation ring. Gwilliam and Haugseng constructed the linear Batalin-Vilkovisky quantization, a derived version of the Weyl quantization of symplectic vector spaces, as a functor of ∞-categories. Chu, Haugseng and Heuts finalized the comparison of the existing models of ∞–operads, showing that they all produce the same homotopy theory. Ungheretti, who defended his thesis in October, proved an $O(2)$–equivariant version of the Jones isomorphism relating the Borel $O(2)$–equivariant cohomology of the free loop space to the dihedral homology of the cochain algebra. In the process, he filled a gap in Jones' classical paper "Cyclic homology and equivariant homology".

4 Comments to the appendix

Appendix—A: External relations. The table lists 83 external collaborators on journal articles (2015: 86, 2014: 73, 2013: 79, 2012: 66), the vast majority international, and we also mention the 162 scientific guests hosted by the center in 2016 (2015: 185, 2014: 155, 2013: 214, 2012: 164), some of these joint with Hesselholt's Bohr professorship. (A guest is someone who gets a building key and office space during their visit.)

Appendix—B: Conferences. B-a lists 4 events at the center and 7 external events. Of the events at the center, 2 were conferences, and 2 were masterclasses. The number of internal events was a bit lower than previous years, though there has been some fluctuation from year to year (2015: 9, 2014: 5, 2013: 15, 2012: 7). **B-b** lists 104 invited center talks distributed on 63 venues. The number of invited talks is significantly higher than past years (2015: 78, 2014: 86, 2013: 86, 2012: 91, 2011: 55, 2010: 67).

Appendix—C: Educational activities. The table lists 14 graduate courses and 1 external mini course. We produced 2 BS and 13 MS, higher than our historical average (MS graduates 2015: 8, 2014: 8, 2013: 5, 2012: 7, 2011: 10). Of the 13 MS students, 4 have currently continued in PhD programs (1 at the center, 1 at Sorbonne Paris Cité, 1 at Computer Science at UCPH, and 1 in Statistics at Oxford). We also mention that a center BS graduate from 2015 is now a PhD student in Computer Science at UCLA.

Appendix—D: External funding. Several grants were initiated in 2016: Galatius's ERC Consolidator grant (12 MDKK), Musat and Rørdam's FNU project (1.5 MDKK), Yalin's Marie Curie postdoc stipend (0.3MDKK), and a Horizon 2020 RISE network (0.2 MDKK at UCPH).

Appendix—E: Awards. Galatius received an ERC Consolidator grant, cf. Appendix D.

Appendix—F: Public outreach. We had 12 outreach activities in 2016, which is similar to last years number. The activies were all aimed at high school students, with the exception of a cover story in *Amer. Math. Monthly*, as well as a chapter in UCPH's Almanac 2017.

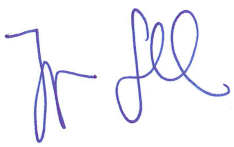
Appendix—H: Publications. We had 45 new preprints added to our CPH-SYM preprint series in 2016 (2015: 48, 2014: 53, 2013: 68; 2012: 48; 2011: 31). 35/0 papers appeared in peer reviewed journals/proceedings in 2016, compared to 41/0 in 2015, 38/5 in 2014, 22/8 in 2013, 29/0 in 2012 and 26/3 in 2011. We have another 23/1 papers in the accepted-in-2016-but-not-yet-appeared category. These are solid numbers.

In terms of top journal publications in 2016, we had 6 publications accepted to our Top-10 list: 1 paper accepted to *Invent. Math.* (in Top-3) authored by Balmer–Sanders (arXiv:1508.03969), 1 paper accepted to *Ann. Sci. École Norm. Supér.* authored by Alm–Petersen (arXiv:1509.09274), 2 papers accepted to *Adv. Math.* authored by Patchkoria (arXiv:1603.04681) and Degrijse (arXiv:1506.06260), and 2 papers accepted to *Geom. Topol.* authored by Cantero–Randal-Williams (arXiv:1304.3006) and Petersen (1603.01137). A paper in *Adv. Math.* (arXiv:1110.0651) mentioned in 2015, and three papers in *J. Reine Angew. Math.* (arXiv:1212.6498, arXiv:1306.0460, and arXiv:1311.6419) mentioned in 2014 finally made it to press.

5 Signature

I hereby confirm the correctness of the information concerning annual accounts, including itemizations. Also, I confirm that the compiled annual reporting, including the appendices, 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, 2017



Jesper Grodal
Professor, Center Director