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

Annual report 2015

(1 Jan - 31 Dec, 2015, "Year 6")

DNRF Centre for Symmetry and Deformation (SYM)

DNRF92

Department of Mathematical Sciences
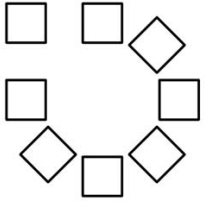University of Copenhagen

Established Jan 1, 2010

Centre for Symmetry and Deformation
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CENTER HIGHLIGHTS 2015

The year 2015 was the first year of our second period, which got off to an excellent start with good progress on our new research agenda, as well as the launching of new broader activities. Our PhD and postdoctoral training programs continued at full volume with 14 PhD students and 14 postdocs at the end of the year.

ACTIVITIES. The center was buzzing with activity all year, hosting 2 conferences, 2 workshops, 5 masterclasses, and 185 individual visitors. A new biannual event was initiated this summer, with the 1st *Young Mathematicians in C*-Algebras* meeting attracting more than 100 participants, mainly MS and PhD students. In the fall, Tikuisis, White, and Winter gave the first in-depth presentation of their recent breakthrough results on quasidiagonality of nuclear C^*-algebras.

RESEARCH. 41 papers were published in 2015, maintaining the new high we reached last year, and 48 new preprints were added to our preprint series CPH-SYM-DNRF92 on arXiv.org. We embarked on our second-period research agenda, with fresh impetus provided by a new assistant professor and 7 new postdocs. Of recent research breakthroughs we mention that Petersen with Alm established a conjecture of Francis Brown and that, in geometric group theory, Brodzki–Cave–Li proved that amenability at infinity is equivalent to exactness for locally compact groups. Worth special mention is also that the classification of graph C^*–algebras this year reached a conclusive state by work of Eilers, Gabe, and collaborators. Several of the papers highlighted last year have now been accepted in top journals: Ozawa–Rørdam–Sato in *GAFA*, Haagerup–Knudby–de Laat in *Ann. Sci. École Norm. Supér.*, Boyle–Schmieding and Kaad–Nest in *J. Reine Angew. Math.*, and the paper by Wahl–Westerland in *Adv. Math.* Again this year, a graduating PhD student received a coveted DFF postdoc stipend, with Li receiving one of only 8 fall FNU stipends.

EDUCATION AND OUTREACH. We continued our strong commitment to building up the MS program, giving 15 graduate courses this year, and incorporating new teaching schemes like a summer school hosted by the Foundation for Danish-Norwegian Cooperation, on Danish-Norwegian research within the center's core area. We likewise continued and broadened our outreach activities, assisting with a 3D visualization display in connection with Glyptoteket's Man Ray exhibition, as well as continuing our dedication towards high school students. Our annual Gaming Café at the Culture Night was augmented with a performance on the interplay between music, mathematics, and painting that attracted 120 attendants.
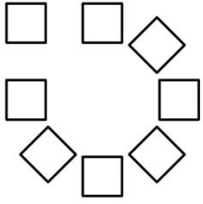
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CENTERHØJDEPUNKTER 2015

Året 2015 var det første år i centrets anden periode som fik en fremragende start med god fremdrift inden for vores nye forskningsmål og med lanceringen af en bredere vifte af aktiviteter. Vores postdoc- og ph.d.-udviklingsaktiviteter fortsatte på fuld kraft med 14 ph.d.-studerende og 14 postdocs ved udgangen af året.

AKTIVITETER. Centret summede af aktivitet året igennem idet vi var værter for 2 konferencer, 2 workshops, 5 masterclasser og 185 individuelle gæster. Et nyt biennalt arrangement startede op denne sommer hvor det første *Young Mathematicians in C*-Algebras*-møde tiltrak over 100 deltagere, primært ph.d.- og kandidatstuderende. I efteråret gav Tikuisis, White og Winter de første dybdegående foredrag om deres nylige gennembrudsresultater for kvasidiagonalitet af nukleære *C**-algebraer.

FORSKNING. 41 artikler blev publiceret i 2015, samme rekordhøje antal som sidste år, og 48 nye preprints blev føjet til vores preprintserie CPH-SYM-DNRF92 på arXiv.org. Vi påbegyndte vores anden periodes forskningsplan med nyt moment tilført i form af en ny adjunkt og 7 nye postdocs. Blandt de seneste forskningsgennembrud bør nævnes at Petersen sammen med Alm bekræftede en formodning af Francis Brown, og inden for geometrisk gruppeteori at Brodzki–Cave–Li beviste at amenabilitet i uendelig for lokalkompakte grupper er ækvivalent med at være eksakt. Det bør videre nævnes at klassifikationsprogrammet for graf-*C**-algebraer er gået ind i en konklusiv fase grundet arbejde af Eilers, Gabe og deres medforfattere. Adskillige af de preprints der blev fremhævet sidste år, er nu blevet accepteret til toptidsskrifter: Ozawa–Rørdam–Sato til *GAFA*, Haagerup–Knudby–de Laat til *Ann. Sci. École Norm. Supér.*, Boyle–Schmieding og Kaad–Nest til *J. Reine Angew. Math.*, samt artiklen af Wahl–Westerland til *Adv. Math.* Også i år modtog en nyudklækket ph.d. et efterstræbt DFF-postdocstipendium idet Li fik et af efterårets blot otte FNU-stipendier.

UNDERVISNING OG FORMIDLING. Vi fortsatte vores dybe engagement i udbygningen af kandidatprogrammet, ved at udbyde 15 kandidatkurser og ved at udvikle nye undervisningsstrategier som en sommerskole holdt hos Fondet for dansk-norsk samarbeid om dansk-norsk forskning inden for centrets kerneområder. Også vores formidlingsaktiviteter blev fortsat såvel som udvidet, idet vi hjalp Glyptoteket med en 3D-visualiseringsinstallation i forbindelse med deres Man Ray-udstilling, samtidig med at vi fortsatte vores indsats rettet mod gymnasieelever. Vores årlige Spillecafé ved Kulturnatten blev udbygget med en forestilling om samspillet mellem musik, matematik og maleri som tiltrak 120 tilhørere.
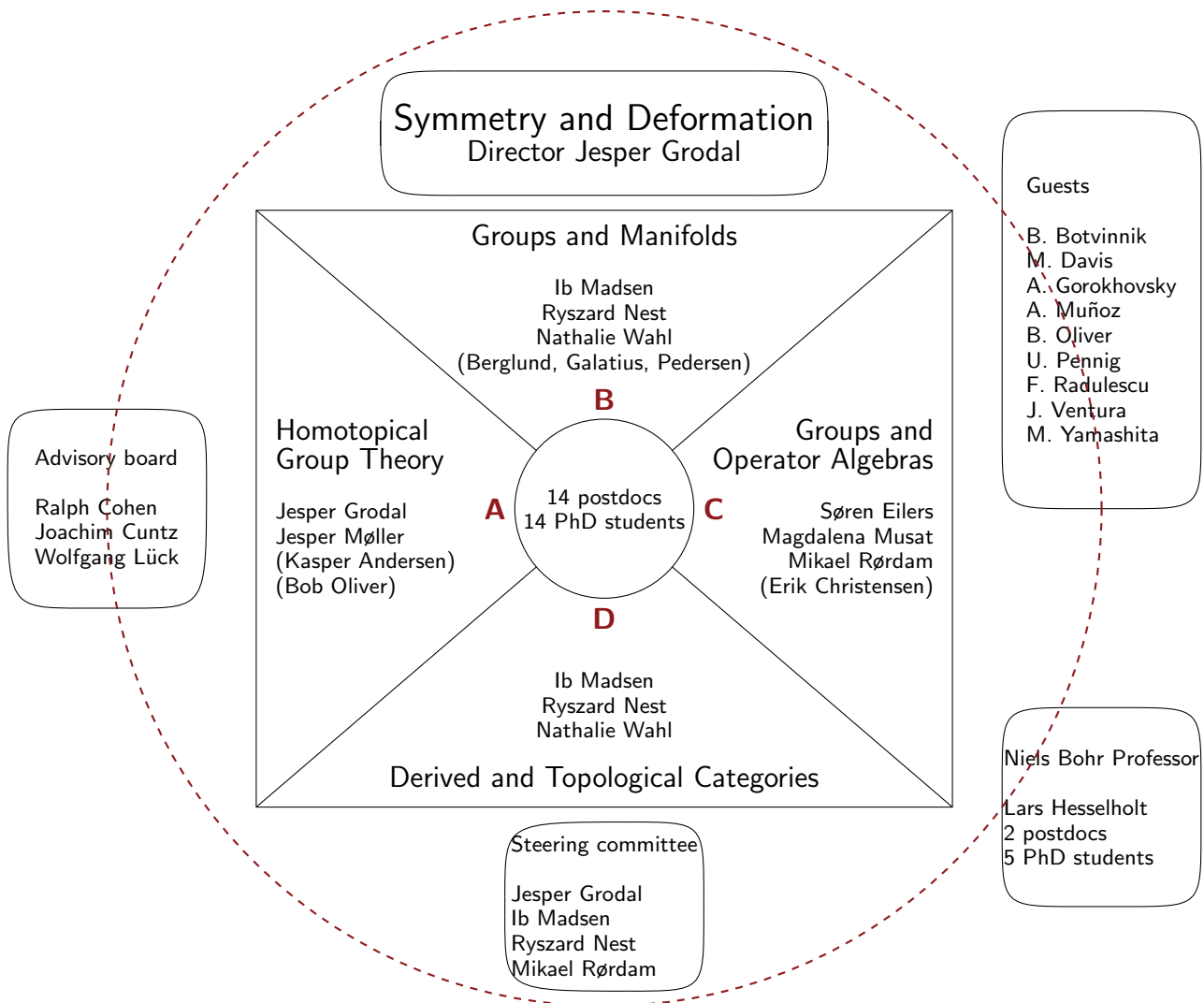
Besøg vores hjemmeside sym.math.ku.dk for mere information.

2 Organization

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

2.1 Scientific staff

The composition of the scientific staff has been adjusted in the following ways since last year:

- Ultimo 2015 the number of postdocs/assist. prof was 14 (ult. 2014: 15; contract: 6).

- Ultimo 2015 the number of PhD students was 14 (ult. 2014: 14; contract: 9).

Four PhD students (Böhme, Krannich, Nielsen, and Proietti) were hired during 2015 to the 3-year PhD program. Of the four PhD students who graduated (Gabe, Gomez Lopez, Grey, and Li), Gabe and Gomez Lopez went to Southern Denmark as teaching staff, while Grey remained at the center in a bridging position. Li received a postdoc grant from the Danish Council for Independent Research to work at Münster.

Seven postdocs (Cave, Gabriel, Goffeng, Haugseng, Heuts, Sprehn, and Wang) were hired in 2015. Eight postdocs left the center: Ando got an assistant professorship at Chiba, Crisp and Meir got postdocs at Bonn and Hamburg, while Knudby and Moi both got postdocs at Münster. Foley and Johansen left academia to work at a scientific consulting company and a software company, while Gandini remained in Copenhagen with his family.

2.2 Visitors

We had 16 long-term visitors in 2015 (of which 7 were PhD students), visiting the center for a minimum of 3 weeks (15 in 2014, 32 in 2013, 21 in 2012), as well as 169 short-term guests (140 in 2014, 214 in 2013, 164 in 2012), some of these joint with Hesselholt's Bohr professorship. Notable long-term visitors in 2015 included our associated member Oliver, together with Ventura, Botvinnik (visiting Madsen), Davis (visiting Wahl), Pennig (visiting Eilers), and Gorokhovsky, Radulescu and Yamashita visiting Nest. Furthermore Muñoz arrived 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 newly hired student assistant Østergaard continued along the same lines as described in previous reports.

2.4 Recruitment and gender strategy

As detailed in previous reports, 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, and that candidates turn down offers from leading US universities to come to Copenhagen is no longer seen as unusual. With regards to gender strategy, we regret the low number of women among our junior faculty, and are aware of research pointing to that women can be overlooked in hiring processes. We therefore give applications from female applicants additional scrutiny, with point-by-point comparison to other people we made offers to. We likewise try to expand the candidate base, by providing offers to top female candidates somewhat outside our main area; but competition is fierce, and naturally there is some drop-off in our competitiveness the further away we get from our core areas.

In terms of senior faculty, the 8 permanent members constitute the search committee for the 4 embedment positions during the second period. One has already been filled with Prof. S. Galatius, coming April 2016, and a second is currently being filled. We expect the two remaining positions to be filled towards the end of the grant period, but the search is ongoing. With 2 women among the permanent members (Prof. Wahl and Assoc. Prof. Musat), our gender balance on the senior level already numerically far exceeds that of the general applicant pool and the department as a whole, but nevertheless we are also actively trying to find female candidates here as well.

2.5 Research integrity

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 independent function is limited to students.

3 Research plan

This is the first year where we report on our new research plan for the period 2015–2019. It is structured under 4 headings **(A)** Homotopical group theory **(B)** Groups and manifolds **(C)** Groups and operator algebras and **(D)** Derived and topological categories. Here the first 3 headings spring out of (A), (B), and (C) of the first period, whereas **(D)** is a new area utilizing synergies both internally and with Hesselholt's Bohr professorship—we refer to our research plan for more details. We have seen good progress in all areas this year, and will report on them separately.

(A) Homotopical group theory

Core: J. Grodal, J. M. Møller.
Visiting: B. Oliver, J. Ventura.
Postdocs: J. Foley, E. Meir, B. Sanders, D. Sprehn.
PhDs: B. Böhme (JG), I. Laude (JG), T. Prytula (JMM).

In Homotopical representations, Grodal's student Laude obtained a description of the mapping space where the source is the classifying space of a finite p–group, and the target is the uncompleted nerve of a p–local finite group of a finite group of Lie type in characteristic p, part of her 2016 PhD thesis. Foley completed his work on recognizing null-homotopic maps into classifying spaces of Kac–Moody groups, mentioned last year. Furthermore, Adem–Grodal advanced their project of getting a homotopical understanding of classical questions about group actions on products of spheres.

In Local structure in discrete groups, Henke's foundational work on subcentric linking systems, initiated when she was an assistant professor at the center, was finally completed, and Møller extended his work on equivariant Euler characteristics. Furthermore Balmer–Sanders gave a description of the spectrum of the equivariant stable category of a finite group, combining the classical works of Quillen and Hopkins–Smith in a novel way. A number of new directions were initiated, e.g., our new postdoc Sprehn identified new non-trivial cohomology classes for finite groups of Lie type in the defining characteristic, and Grodal made important first steps in a homotopical understanding of endotrivial modules for finite groups of composite order; we hope to report on these developments in detail next year.

(B) Groups and manifolds

Core: I. Madsen, R. Nest, N. Wahl. (Associated: E. Pedersen.)
Visiting: B. Botvinnik, M. Davis.
Postdocs: D. Degrijse, G. Gandini, D. Petersen (Assist. Prof.), G. Wang.
PhDs: M. Grey (IM), M. Krannich (NW), M. Lopez (EKP).

Madsen, togther with Berglund, continued his study of automorphism groups of connected sums of products of a sphere with itself, describing the rational cohomology ring of the block diffeomorphisms of such manifolds in terms of "hairy" graphs homology. Combined with the work of Galatius–Randal-Williams, this shows that the cohomology of block diffeomorphisms and of actual diffeomorphisms agree in a much larger range than expected. Grey, who defended his PhD thesis in November, generalized the work of Berglund–Madsen to a larger class of manifolds, now including connected sums of products of spheres of different dimensions. Our new assistant professor Petersen made progress in the study of the moduli space of surfaces with marked points: He established a conjecture of Tavakol about the structure of the cohomology of the moduli space of pointed surfaces with rational tails, and together with Alm, gave a new description of the cohomology of the moduli space of pointed genus zero surfaces with punctures, compatible with their gluing structure, establishing a conjecture of Francis Brown. Degrijse gave, together with Leary, the first examples of compatible families of representations of finite subgroups of a group that does not come from a vector bundle over the classifying space for proper

actions of that group, for a group with cocompact such classifying space; he also gave a characterization of being a locally virtually cyclic group in terms of Bredon cohomology. Gandini and Wahl proved that the automorphism groups of right angled Artin groups satisfy homological stability under taking products, giving further evidence for a conjecture of Wahl about the automorphism groups of powers of a group.

(C) Groups and operator algebras

> **Core:** S. Eilers, M. Musat, M. Rørdam. (Associated: E. Christensen.)
> **Visiting:** U. Pennig, A. Muñoz, M. Yamashita.
> **Postdocs:** H. Ando, S. Arklint, C. Cave, T. Crisp, D. Enders, O. Gabriel, M. Goffeng, R. Johansen.
> **PhDs:** R. Bryder (MM), M. Christensen (MR), J. Gabe (SE/RN), K. Li (RN/UH), M. Andersen (MR), K. Olesen (MM/UH), E. Scarparo (MR).

Analytic and geometric group theory, and applications to operator algebras. Graduating PhD student Li, together with former center PhD student Knudby, made progress in understanding the different notions of exactness, as well as coarse embeddability, for locally compact groups, generalizing the known results for discrete groups. Furthermore, in a recent breakthrough, Brodzki–Cave–Li proved that amenability at infinity is equivalent to exactness for locally compact groups. In index theory, postdoc Goffeng established a relation between analytical and topological surgery groups using unbounded KK–theory. Finally, Crisp, together with coauthor Higson, extended in a series of papers Bernstein's homological methods, originally in p–adic representation theory, to representation theory of real Lie groups.

In Dynamical systems and symmetries of C^*-algebras, the classification of graph C^*–algebras reached a conclusive state by work of Eilers and his student Gabe. Indeed, Eilers, Restorff, Ruiz, and former center PhD student Sørensen resolved the geometric classification problem for unital graph C^*–algebras completely, and Gabe found a classification result for the complete class of purely infinite graph C^*–algebras. Both results allow the ideal structures to be infinite, requiring completely new tools. In another direction, as an unexpected bonus of experimental work in collaboration with the Villum Network for Experimental Mathematics, postdoc Johansen, with Sørensen resolved, in the negative, the long open question of whether the so-called Cuntz splice (developed in the 1990's for C^*–algebras in groundbreaking work of Cuntz and Rørdam) is an invariant of Morita equivalence of Leavitt path algebras.

(D) Derived and topological categories

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

This is a new area in our research plan, which aims to calculate derived invariants, such as flavors of Hochschild homology in a wide range of contexts, including Topological and Algebraic K-theory, string topology, and D–modules, using techniques from homotopy theory and higher algebra. We hired two postdocs (Haugseng and Heuts) and two PhD students (Nielsen and Proietti) in the area. There has been a number of developments of which we mention a sample: Heuts has extended Goodwillie's theory of approximations to the setting of higher categories. Ungheretti has made progress on extending the well-known Jones isomorphism, identifying the circle-equivariant cohomology of the free loop space with the cyclic homology of cochains on the space, replacing the circle by isometries of the plane. Patchkoria and Sagave clarified the relationship between two different models for topological Hochschild homology, and Madsen and Moi, together with Hesselholt, has made progress towards a Quillen type localization theorem for real algebraic K–theory. Bressler–Gorokhovsky–Nest–Tsygan constructed a curved differential graded Lie algebra describing the deformation complex of algebroid stacks—this is the first step towards the question of formality for algebraic stacks, of our research plan.

4 Comments to the appendix

Appendix—A: External relations. The table lists 86 external collaborators on journal articles (2014: 73, 2013: 79, 2012: 66), the vast majority international, and we also mention the 185 scientific guests hosted by the center in 2015 (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 9 events at the center and 1 external workshop. Of the events of the center, 2 were conferences, 2 were workshops, and 5 were masterclasses. The number of internal events was in line with previous years, though there as been some fluctuation from year to year (2014: 5, 2013: 15, 2012: 7). **B-b** lists 78 invited center talks distributed on 49 venues. The numbers are similar to the last two years, but significantly higher than the first couple of years (2014: 86, 2013: 86, 2012: 91, 2011: 55, 2010: 67).

Appendix—C: Educational activities. The table lists 15 graduate courses. We produced 6 BS and 8 MS, close to our historical avarage (MS graduates 2014: 8, 2013: 5, 2012: 7, 2011: 10). Of the 8 MS students, 1 has currently continued in a PhD program (as part of Hesselholt's Bohr Professorship); the ratio continuing in PhD programs is lower than usual, but attributed to ordinary fluctuation.

Appendix—D: External funding. As expected the external funding in 2015 took a steep drop, as several of our big grants ran out. However, in the year passed, we did manage to secure an ERC consolidator grant (Galatius) and a Marie Curie grant (Wahl/Yalin), which will kick in 2016, so we expect some rebound in the coming years.

Appendix—F: Public outreach. We had 11 events in 2015, which equals last years number, but we are broadening out with respect to venues, as already mentioned in the highlights. In terms of challenges, the international composition of our staff gives restrictions, since many outreach activities should be in danish—we try to compensate e.g., through the Lycée Français Prins Henrik.
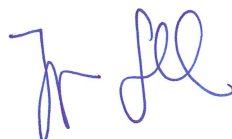
Appendix—H: Publications. We had 48 new preprints added to our CPH-SYM preprint series in 2015 (2014: 53, 2013: 68; 2012: 48; 2011: 31). 41/0 papers appeared in peer reviewed journals/proceedings in 2015, compared to 38/5 in 2014, 22/8 in 2013, 29/0 in 2012 and 26/3 in 2011. We have another 19/2 papers in the accepted-in-2015-but-not-yet-appeared category. These are solid numbers.

In terms of top journal publications in 2015, we had 4 publications accepted to our Top-10 list: 1 paper accepted to *Ann. Sci. École Norm. Supér.* authored by Haagerup–Knudby–de Laat (arXiv:1412.3033), 2 papers accepted to *J. Reine und Angewandte Mathematik* authored by Boyle–Schmieding (arXiv:1501.04695) and Kaad–Nest (arXiv:1403.7937), and 1 paper accepted to *Advances* authored by Wahl–Westerland (arXiv:1110.0651). Papers in *Advances* (arXiv:1308.3951, arXiv:1209.0937) mentioned in earlier years finally made it to press. We also mention that Reeh's paper arXiv:1302.4628 and the Ozawa–Rørdam–Sato paper arXiv:1404.3462, mentioned in last year's report, were accepted to *Algebra & Number Theory* and *GAFA* respectively—these are en par with *Geometry & Topology* but not on our Top 10 list, since they are subject journals a bit outside our main area (see also our midway self-evaluation report).

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, 2016   Jesper Grodal
                                                                 Professor, Center Director