Annual report 2017
(1 Jan - 31 Dec, 2017, “Year 8”)

DNRF Centre for Symmetry and Deformation (SYM)
DNRF92
Department of Mathematical Sciences
University of Copenhagen

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The year 2017 took the recognition of the next generation of permanent faculty at the center to a new level, with Søren Galatius receiving the Danish Elite Researcher Prize 2017, and Nathalie Wahl receiving an ERC Consolidator Grant. This raises the total number of ERC grants the center has received to 5, the highest number for any single research center in Denmark, we believe.

Research continued to charge ahead, full speed, with new papers in *Annals*, *JAMS*, etc., and many events dispersed throughout the year.

**ACTIVITIES.** The center hosted 2 large conferences, a workshop, 5 masterclasses, and 168 individual visitors in 2017 making for a busy year. It being an odd year, we hosted the Young Mathematicians in C*-algebras, which this time featured minicourses by Kate Juschenko and Guoliang Yu, in addition to short talks by budding operator algebraists from around the world. As a new initiative, the event was preceeded by a smaller workshop entitled Young Women in C*-Algebras, giving female researchers an extra chance to interact, before the main event. It was deemed a great success!

**RESEARCH.** The year featured a number of research breakthroughs: Barthel and coauthors released their paper showing that chromatic homotopy is algebraic, “asymptotically in the prime $p$”, using a completely new toolbox, inspired by mathematical logic. Likewise Grodal–Lahtinen connected different areas of mathematics by establishing a new and unanticipated connection between string topology and the cohomology of finite groups of Lie type. And Hingston–Wahl, in a more geometric direction, showed that string topology can be used to determine intersection multiplicities. Highlights from previous years got accepted in the very top journals, with the Galatius–Randal-Williams work on homological stability of high dimensional manifolds appearing as a two-part treatise in *JAMS* and *Annals of Math* and the work of Wang–Xu on smooth structures on spheres likewise appearing in the Annals. In all we had 41 published papers and 44 additions to our preprint series CPH-SYM-DNRF92 on arXiv.org in 2017, with 10 postdocs and 11 PhD students at the center.

**EDUCATION AND OUTREACH.** The center supervised 7 PhD theses, 11 MS thesis, and 10 BS theses, and taught 15 courses directly related to the center’s research. Both the number of graduating PhD students and number of BS theses were new records, the last number reflecting a deliberate effort to involve more postdocs in undergraduate supervision.

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**CENTERHØJDEPUNKTER 2017**

2017 tog anerkendelsen af den nye generation af faste medarbejdere på centret til et nyt niveau, idet Søren Galatius modtog EliteForsker prisen, og Nathalie Wahl modtog et ERC Consolidator Grant. Det betyder, at centeret nu i alt har fået 5 ERC bevillinger, hvilket, så vidt vi ved, er det højeste antal for et enkelt forskningscenter i Danmark. Forskningen fortsatte på fuld tryk, med nye artikler i *Annals, JAMS*, osv. og mange begivenheder i løbet af året.

**AKTIVITETER.** Centret var vært for 2 store konferencer, en workshop, 5 masterclass’er og 168 individuelle gæster, så 2017 har været et travlt år. Som i andre ulige år var vi vært for Young Mathematicians in C*-algebras, der i år havde minikurser af Kate Juschenko og Guoliang Yu, samt korte oplæg fra unge operatoralgebraikere fra hele verden. Som noget nyt blev der holdt en mini-workshop med titlen Young Women in C*-algebras op til konferencen. Det gav de kvindelige forskere en ekstra mulighed for interaktion inden hovedarrangementet - det blev en stor succes!

**FORSKNING.** Året bød på flere nye forskningsgennembrud: Barthel og hans medforfattere frigav deres arbejde, hvor de viser at kromatisk homotopiteori er algebraisk, "asymptotisk i primitallet \( p \)", ved at benytte helt nye metoder, inspireret af matematiske logik. Ligeledes fandt Grodal–Lahtinen nye sammenhænge mellem forskellige områder af matematikken, ved at udvikle en ny og uventet forbindelse mellem strengtopologi og kohomologien for endelige grupper af Lie type. I en mere geometrisk retning viste Hingston–Wahl at strengtopologi kan bruges til at finde snitmultipliciteter.


**UNDERVISNING OG FORMIDLING.** Vi vejledte 7 ph.d.-afhandlinger, 11 specialer og 10 bachelorprojekter, og underviste 15 kurser inden for centret’s fagområder. Det er det højeste antal færdiggjorte ph. d.’er og bachelorprojekter siden centerstart, og specielt den sidste rekord afspiller vores målrettede indsats for at involvere postdocs i vejledningsarbejdet.

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Danish National Research Foundation

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2 Organization

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

2.1 Scientific staff

The senior academic staff did not undergo changes this year, except that Galatius was on leave during the spring semester and Petersen during the fall. In terms of postdoc and PhD students, the status looks as follows:

- Ultimo 2017, the number of postdocs/assist. prof. was 10 (ult. 2016: 9; contract: 6).
- Ultimo 2017 the number of PhD students was 11 (ult. 2016: 14; contract: 9).

Four PhD students (Borys, Schmitt, Duan, and Leip) were enrolled during 2017, Duan fully financed by a Chinese stipend, and in addition two double-degree students (Ewert and Mukherjee) from Göttingen where associated. 7 PhD students graduated in 2017: Prytula is now a research fellow at the University of Southampton, Scarpato holds a postdoc position at the Federal University of Santa Catarina in Florianópolis in his native Brazil, and Canlubo is a high school teacher associated to the University of the Philippines. The four graduating danes, Lolk Andersen, Bryder, Christensen, and Laude, all took jobs in private companies in Denmark.

Three postdocs (Szabó, Gritschacher, Habliscek) were hired in 2017, and two additional postdocs joined the center on external grants: Börjeson with a stipend from the Wallenberg Foundation and Muñoz on
a Villum Experiment grant. The funding situation further improved late in the year with postdocs Szabó and Barthel receiving Marie Curie grants. Four postdocs left the center in 2017: Heuts is now an tenure track assistant professor at the Universiteit Utrecht, Kupers holds a prestigious Benjamin Pierce Instructorship at Harvard, and Sanders holds a postdoc position at the EPFL, en route to a tenure-track position at UC Santa Cruz. Gabriel left for industry in Paris.

2.2 Visitors

We had 15 long-term visitors in 2017 (of which 4 were PhD students), visiting the centre for a minimum of 3 weeks (11 in 2016, 16 in 2015, 15 in 2014, 32 in 2013, 21 in 2012), as well as 153 short-term guests (146 in 2016, 169 in 2015, 140 in 2014, 214 in 2013, 164 in 2012), some of these joint with Hesselholt’s Bohr Professorship.

2.3 Administration

Since only two years remain of the center, an administrative priority has been to attempt to embed as many center rutines as possible on the department level, to ensure their continuity beyond the duration of the center. To aid with this, Grodal took over as head of section for Algebra, Topology, and Functional analysis in February, and most administrative meetings are carried out as joint section and center meetings. In terms of postdoc recruitment we managed to run our postdoc hiring through MathJobs, an international site for math recruitment run by the American Mathematical Society, which we have been prevented from doing in previous years by red tape—this has increased our ability to attract applicants and at the same time eased the administrative burden significantly. In terms of day-to-day administration, Thorseth replaced Arklint as centre administrator, as of November, continuing along the same lines of work in collaboration with centre student assistant Eilsøe-Madsen.

2.4 Recruitment and gender strategy

We steadily continue our push to obtain better gender balance, and an important part of this equation is to reach as many female applicants on our annual PhD and postdoc calls. As something new this year, our postdoc applications are handled through MathJobs, with makes application easier, hence attracting more applicants, and also significantly cuts down on our administration, due to automatisation of the processes surrounding letters of recommendation. 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, and also make an effort to help with two-body problems and other such matters to the ones to which we extend offers. Several people declined our offers, due to competition from the very top US universities, but we did manage to hire one female postdoc and one female PhD student in 2017, who will start in 2018.

In terms of senior faculty, the 9 permanent members constitute the search committee for the 4 embed- ment 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 plagiarism 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 report on progress on our 2015–2019 research plan, 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. Aumonier, B. Oliver, J. Ventura. |
| PhDs: B. Böhme (JG), Z. Duan (JMM), J. Hunt (JG), I. Laude (JG), T. Prytula (JMM). |

In terms of homotopical groups, Grodal–Lahtinen established a new and unanticipated connection between string topology and the cohomology of finite groups of Lie type, utilizing the homotopical description of the $p$–completed classifying space of a finite group of Lie type. And Barthel–Castellana–Heard–Valenzuela also extended the reach of homotopical methods, by providing stratification and duality results to the setting of homotopical groups. Møller advanced his program of understanding equivariant Euler characteristics of $p$–subgroup complexes, by calculating the equivariant Euler characteristic of the Tits building associated to a general linear or unitary group over a finite field.

There were also a lot of new developments in chromatic homotopy theory, where we can just name a few highlights. Barthel, Schlank, and Stapleton showed that $L_n$–local homotopy theory has an algebraic model, “asymptotically in the prime $p$”, where both the statement and methods of proof are inspired by mathematical logic. Likewise Barthel and Hausmann, together with 4 authors from Regensburg extended the work of Balmer–Sanders reported on last year, by giving a complete description of the Balmer spectrum of the $G$–equivariant stable homotopy category, in the case were $G$ is a finite abelian group.

Two PhD students graduated in this area: Laude successfully defended her thesis under the direction of Grodal, on maps between uncompleted classifying spaces of $p$–local finite groups, and Prutula defended his thesis under the direction of Møller, describing geometric features of systolic complexes arising from the actions of hyperbolic isometries.

(B) Groups and manifolds

| Core: S. Galatius, N. Wahl. (Associated: I. Madsen.) |
| Visiting: M. Barucco, C. Bernard, M. Meisel, J. Reinhold. |
| PhDs: M. Jansen (SG), M. Krannich (NW). |

Hingston and Wahl showed that a lift of the Goresky–Hingston string topology coproduct can be used to detect the intersection multiplicity of homology classes, a geometric invariant of homology classes in the loop space of a manifold. They also show that this coproduct is homotopy invariant, giving evidence for their conjecture that compactified string topology more generally is homotopy invariant. Krannich constructed a canonical resolution of any $E_2$-algebra, whose connectivity encodes homological stability properties of the algebra, building on the earlier work of Randal-Williams and Wahl. The main examples considered in his paper are configuration spaces of manifolds and the moduli spaces of manifolds earlier considered by Galatius–Randal-Williams. He deduces in those cases new stability results with twisted coefficients and extends the realm of application of homological stability. In a paper on h-principles based on unpublished ideas of the experts in the field, including Galatius, Kupers gives a homotopical version of Vassiliev’s h-principle, gives an alternative proof the contractibility of the space of framed functions, and proves a version of Mather–Thurston theory for foliations.
(C) Groups and operator algebras

Core: S. Eilers, M. Musat, M. Rørdam. (Associated: E. Christensen.)
Visiting: M. de Chiffre, S. Schmieding, L. Vas.
Postdocs: S. Arklint, C. Cave, O. Gabriel, A. Muñoz, G. Szabó.
PhDs: C. Borys (MR/MM), K. Brix (SE), R. Bryder (MM), M. Christensen (MR), M. Lolk Andersen (MR), E. Scarparo (MR).

Following up on an earlier paper of Grigorchuk–Musat–Rørdam, Rørdam proved that any metrizable Choquet simplex can be the trace simplex of a just-infinite C*-algebra. In another paper, Rørdam, together with Farah, established that the stable rank is axiomatizable in logic of metric structures, and hence is Kadison–Kastler stable. Musat, while visiting CNRS Associate Professor at IHP in Paris, gave a mini-series of lectures and continued her research on questions related to Tsirelson’s conjecture and factorizable channels. Szabo showed that multiflows on strongly self-absorbing Kirchberg algebras with the Rokhlin property are unique up to cocycle conjugacy. Brix proved the converse of a statement in an almost 40 years old paper of Cuntz–Krieger, with the effect of completely characterizing when two one-sided shift spaces are conjugate in terms of their associated operator algebras. Four PhD students defended their thesis in 2017 on topics related to this part of the proposal: Lolk Andersen, who solved several problems on the recently developed theory of C*-algebras arising from separated graphs, Scarparo, who proved that the C*-algebra of a topological full group under the Koopman representation is not AF, and confirmed the conjecture that a group C*-algebras is AF if and only if the group is locally finite in the case of elementary amenable finitely generated groups. Bryder gave a necessary and sufficient condition for the intersection property for crossed products in terms of properties of the injective envelope, and with Ivanov and Omland he gave examples of HNN-extensions for which the reduced C*-algebras have the unique trace property, but are not C*-simple. Finally, Christensen in his thesis studied regularity properties of C*-algebras and how these regularity properties are reflected in their associated central sequence algebras.

(D) Derived and topological categories

Core: R. Nest, D. Petersen, N. Wahl. (Associated: I. Madsen)
Visiting: C. Davis, M. Goffeng.
Postdocs: M. Hablicsek, R. Haugseng, G. Heuts.
PhDs: C. Canlubo (RN), M. Leip (LH/JG), E. Nielsen (NW), V. Proietti (RN), P. Schmitt (RN).

Haugseng, together with Gepner and Kock, gave a description of infinity-operads in terms of monads. In another, single-authored paper, Haugseng gave an alternative description of infinity operads, now as an algebra in symmetric sequences. Both these results are lifts of the classical theory of operads to the modern infinity categorical language. Last year’s work of Chu–Haugseng–Heuts allows to compare these descriptions to earlier definitions. In a short paper, Heuts, together with Eldred, Mathew and Meier, lifted a part of chromatic homotopy theory to the world of infinity categories, giving a description of the v_n-periodic localization of the infinity category of spaces, as an algebra over a certain monad. Nest, together with Kaad and Wolfson, constructed a universal three-cocycle, the higher dimensional analogue of the universal central extension of the loop groups appearing in string theory. The construction also provides an explicit semi-universal formula for the values of the multiplicative Chern character on the third algebraic K-group, generalising the Tate symbol on the K-theory of fields. In analogy with the two-cocycle associated to a polarized Hilbert space, the construction extends the known formulas for Tate spaces to the case of smooth, instead of analytic, functions and to the group of invertible elements in non-commutative algebras. Nest, together with Li and Echterhoff, extended the Baum–Connes isomorphism to a class of algebraic groups over local function fields, using the Mackey machinery for the study of
the reduced duals of the groups in question. Canlubo defended his PhD thesis in which he defines and studies a notion of a non-commutative covering space using Galois theory of Hopf algebroids.

4 Comments to the appendix

Appendix—B: Conferences. B-a lists 8 events at the centre and 3 external events. Of the events at the centre, 2 were conferences, 1 was a workshop, and 5 were masterclasses. The number of internal event was slightly higher than usual, in particular due to a good number of postdocs organizing masterclasses (2016: 4, 2015: 9, 2014: 5, 2013: 15, 2012: 7). B-b lists 62 invited centre talks distributed on 40 venues. The number of invited talks was lower than usual and balances exceptionally high activity in 2016; however there may also be differences in data collection, so one should probably not read too much into this. (Previous numbers: 2016: 104, 2015: 78, 2014: 86, 2013: 86, 2012: 91, 2011: 55, 2010: 67.)

Appendix—C: Educational activities. The table lists 1 undergraduate course, 14 graduate courses, 1 PhD course and 2 external mini courses. This is close to our usual numbers, but behind the numbers lies a continuous streamlining in the course offering. In 2017 we produced 11 BS (2016: 2, 2015: 6, 2014: 6) and 10 MS (MS graduates 2016: 13, 2015: 8, 2014: 8, 2013: 5, 2012: 7, 2011: 10). We notice a significant jump in the number of BS students supervised, which is due to a successful effort to have postdocs supervise BS projects. Of the MS students only one Duan continued in a PhD program, and the rest quickly found jobs, predominantly in IT.

Appendix—D: External funding. Again this year we had some notable success with funding on the European level, with a new ERC consolidator grant and 2 new Marie Curie grants.

Appendix—E: Awards. Galatius received the Danish Elite Research Prize 2017 and Grodal was elected Fellow of the American Mathematical Society.

Appendix—F: Public outreach. We had 9 outreach activities in 2017, which is a bit lower than last year’s number, but within the same ballpark. The activities covered a wide range of formats: a permanent display at the new LEGO house in Billund, a well-attended activity at Kulturnatten, as well as the usual high school aimed activities.

Appendix—H: Publications. We had many publications accepted in excellent journals this year, with a record number of papers in our old “Top-10” journals. We had 44 new preprints added to our CPH-SYM preprint series in 2017 (2016: 45, 2015: 48, 2014: 53, 2013: 68, 2012: 48, 2011: 31). 41/0 papers appeared in peer reviewed journals/proceedings in 2017, compared to 35/0 in 2016, 41/0 in 2015, 38/5 in 2014, 22/8 in 2013, 20/0 in 2012 and 26/3 in 2011. The book by Eilers mentioned in last year’s report also made it to press in 2017, and we have another 17/0 papers in the accepted-2017-but-not-yet-appeared category. These are solid numbers in line with previous years – generally we are not striving to increase the number of publications, but rather raise the quality as high as possible.

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, 2018

Jesper Grodal
Professor, Center Director