Annual Report

Funding Programme:	Helmholtz Young Investigators Groups
Project ID No.:	HZ-NG-603
Project Title:	Strings and Cosmology – an Interface for Testing Fundamental Theories
Group Leader:	Alexander Westphal
Helmholtz Centre:	DESY Hamburg
Participating University:	
Report Period (=Calendar Year):	01/2014-12/2014

1) Group Structure

Please report briefly on the structure and personnel development of your group.

Francisco Pedro completed his postdoctoral position in the group in fall 2014. He was successful in obtaining a 2nd postdoctoral position with the group of Luis Ibanez at the Autonomous University of Madrid, Spain, where he started the same fall.

Benedict Broy (Master at Hamburg U.) and David Ciupke (Master at Goettingen U.) have been continuing their PhD projects throughout 2014.

We were initially successful to hire Timm Wrase (at that time at Stanford U. after being at Cornell U.) for a final 2-year postdoctoral position, with the 2nd year being covered by DESY. However, last summer Timm was offered a 5-year junior faculty position in Vienna, with the option for tenure-track coupled to applying for a national Austrian research grant. Given the incommensurability of our own offer, we were not able to keep him for the postdoctoral position. As this was on such short notice and far outside the annual fall hiring cycle of high-energy theoretical physics postdocs, we had no possibility to refill the position with a newly selected candidate.

Fortunately though, a local postdoc here at DESY, Ido Ben-Dayan, whose 2-year contract finished the same fall of 2014, was both interested and more than well-qualified enough for the project. Consequently, we decided to offer Ido Ben-Dayan the final postdoc-year in the group as 3rd year extension to his stay at DESY. Ido hence came aboard in 11/2014, and will stay with the group until its finish in 09/2015.

2) Network

Please describe how you / your research group are integrated within the Helmholtz Centre and the partner university (e.g. as member of committees).

The YIG is fully integrated in the activities of the theory group at DESY, and collaborates very closely with the II. Institute for Theoretical Physics of Hamburg University. In addition, the YIG group leader remains a PI of the DFG Collaborative Research Center SFB 676, C6.

The YIG has co-organized the 2014 workshop “Inflation after Planck”:

https://indico.desy.de/conferenceDisplay.py?confId=9421

at DESY.

3) Satisfaction

How satisfied are you with the general working conditions provided by the Helmholtz Centre / partner university? Is there anything that meets your criticism?

In general, I am very satisfied with the working conditions at DESY. The interaction within the theory group, and with the work-related travel office (the part of administration I have to deal with by far the most often) is characterized by a very flexible and informal, friendly style, and almost absent hierarchies. This is very beneficial for the scientific work.

I may also mention here, that DESY has a very generous travel funding arrangement to the extent, that I have never seen any scientifically justified travel to a conference or seminar visit by any member of the theory group being denied. The funds available in particular for the travel of students and postdocs as well as for inviting short- and long-term visitors by DFG Collaborative Research Center SFB 676 add to this. This is significant, as reports in particular from the University situation of travel and visitor funds sound significantly worse. Consequently, this allows for a rich structure for international scientific exchange on conferences, and a lively local seminar and visitor program.

There are 2 complaints I may have – one practical, and one structural:

1) The first, practical one, concerns the access to the Helmholtz-funded part of the material resources budget of a YIG (like the acquisition of computing hardware in particular). It does not seem very useful and reasonable that acquisitions using the Helmholtz-funded part have to approved centrally by the relevant DESY directorate.

In particular, there is information, that e.g. similarly structured Emmy-Noether groups at the University, or also YIGs in the experimental departments of DESY, do not seem to have the same administrative hurdle to clear when they provide group members with personal computing hardware. (One should also bear in mind, that providing quick and effortless access to the most recent and up-to-date personal computing hardware for scientists is a relevant criterion for future postdoc offers, as I know very well from personal experience that most of the e.g. US-based excellent postdocs factor such things into their decision on whether to accept an offer!)

2) the structural problem: this concerns the salary levels/structures of the YIG PIs. At least at DESY, they are classified in the public sector contract system TVÖD at level E14, sublevel ususally 3 initially. This is seriously insufficient in two ways:

- I have by now knowledge, that the comparable Emmy-Noether-Young-Investigator-Groups classify their group leaders by default into E15. It is unreasonable and unattractive for the Helmholtz-YIGs to offer a subpar salary grouping compared to Emmy-Nother-groups, and it disadvantages the Helmholtz-YIG group leaders in their future salary negotiations when they are granted tenure. This should be remedied, the earlier the better.

- the whole E14/E15 public sector after-tax salary level in completely insufficient in comparison with the after-tax salary from an average university W2 position. Practically all of the YIG-group leaders teach and take Master and/or PhD students, hence performing the same work and roles as their peers with direct university positions. It is not reasonable and moreover unfair to pay unequally for equal work. This inequality subtracts significantly from the attractivity of all the various YIG-groups, in particular for excellent foreign scientists as potential future applicants.

4) Scientific Progress / Milestones

How has your work plan progressed? Which important milestones could be achieved during the report period? Is the progress of your work in accordance with original planning or has the work plan been changed?

Inflation & string theory:

In 2014, we saw the first detection of degree angular scale B-mode polarization in the cosmic microwave background radiation (CMB) by the BICEP2 telescope. If inflation was driven by a scalar field with a 'large' trans-Planckian field displacement, its energy scale is that of Grand Unified Theories (GUTs) at about 10^{16} GeV, and it produces a nearly scale-invariant power spectrum of primordial gravitational waves (tensor modes), which would cause a B-mode polarization signal in the CMB of roughly the same strength as the signal seen by BICEP2. Their very high energy scale renders these large-field inflation models sensitive to quantum gravity or string theory effects. Hence, the BICEP2 B-mode signal, and the question to which degree it originates from inflationary tensor modes caused a spark of theoretical interest. Since then, the reanalysis and joint analysis of the full temperature data from the Planck satellite and part of its own B-mode data showing unexpectedly strong dust foregrounds in our galaxy together with BICEP2 and its successor, the Keck Array, has driven a large burst of analysis and construction of large-field inflation models in string theory, many of them based on the mechanism of axion monodromy which the YIG group leader co-discovered in 2008. The members of the YIG consequently got strongly involved during 2014 in this process of analyzing the phenomenological range of string theory models of large-field inflation for B-mode production. This served the project well, as it showed that the landscape of large-field inflation models in string theory is significantly wider and varied than many anticipated earlier, and this needs now to be taken into account for the projects goal of analyzing the landscape of string inflation models. It is therefore foreseeable that, given these recent developments, a closure of the projects objectives may not be reachable by the project end in September 2015.

The joint work of the YIG on this expanded understanding of large-field inflation in string theory resulted in series of publications: 1404.7773 , 1405.0270 , 1405.3652 , 1407.2562 , 1412.1814, and an invited review article: 1409.5350 by the YIG group leader, which was also published as part of a book monograph ("Perspectives on String Phenomenology", World Scientific, 2015).

In parallel, we studied in 1408.5904 the theoretical structure and CMB observational consequences of a class of inflationary models with an asymptotically exponentially flat potential similar to the original $R+R^2$ inflation model by Starobinsky. These so-called 'strong non-minimal coupling attractor' models first introduced by Renata Kallosh, Andrei Linde, and Diederik Roest, continue to provide a very good description to the joint constraints and analysis of the Planck CMB temperature, E-mode and B-mode polarization results and the BICEP2/Keck Array B-mode results with a tensor mode signal one order of magnitude below that of large-field models (and thus in reach of a future dedicated satellite experiment). We looked at generic perturbations of the attractor mechanism, and found in 1408.5904 that they lead exponentially rising corrections to the scalar potential, which shorten the exponentially flat inflationary plateau to finite length, create an asymmetric inflection point in the potential and drive a suppression of CMB temperature power at large angular scales due to the steepening of the potential arising from the rising exponential corrections. There are persistent hints in the CMB temperature data from both WMAP and Planck including its latest results for such a suppression of CMB temperature power a large angular scales. This renders models capable of generating inflationary power spectra of curvature perturbations with power suppression at large angular scales particularly interesting.

Driven by this interest, in 1407.1048 we undertook a general analysis of the influence on the CMB temperature power spectrum of an arbitrary pre-inflationary phase of scale-factor evolution transiting into slow-roll inflation late enough to leave just the barely enough 60 e-folds of slow-roll. We found a general expression allowing us to parametrize the effects of the pre-

inflationary phase on the large-angular power spectrum in terms of just the equation-of-state parameter of the pre-inflationary regime. The suppression of CMB power at large angular scales seen in our analysis 1408.5904 of the attractor mechanismmodels were then seen to be a special case of our general analysis in 1407.1048.

Finally, we were able to show in 1411.6010, that certain classes of the perturbed strong-coupling attractor models analysed in 1408.5904 have dual descriptions in terms of an f(R)-theory, where we were able to obtain the function f of the Ricci scalar curvature R either exactly or asymptotically for large R in the inflationary regime. The functions f(R) we found in 1411.6010 generalize Starobinsky's original $R+R^2$ into an infinite series of R^n corrections with computable coefficients, which resum into a non-analytic fractional power functional form of f(R). The presence of this infinite series and their resummation into a nontrivial functional form is mandated by the rising exponential corrections to the potential in Einstein frame, and thus constitute a clear effect of possible ultraviolet completions of Starobinsky's model. In particular, we could show that analogous rising exponential terms limiting the width of exponentially flat inflationary plateau arise in the type IIB string theory models of fibre inflation. Hence, we were able to argue in 1411.6010 that fibre inflation, and some slight variations of its original setup we constructed there, very plausibly provide a direct UV completion in string theory of Starobinky's inflation model. Having this UV completion mandating the rising exponential corrections in turn causes the whole series of higher-derivative R^n corrections to the Starobinsky model, and allows us compute their coefficients.

5) Financial Plan / Time Schedule
Can you comply with the financial plan and time schedule or do you see a need for adjustment?

The budget proves so far fully sufficient for the research activities undertaken.

The project is on track thematically and having reached a significant part of its objectives. However, along the way some of the necessary steps and results turned out to require more extensive work and/or we realized that some of the results we are building were derived in the literature for only smaller parts of the string landscape than anticipated.

This has delayed the completion of the first major milestone into the beginning of 2015, where we are nearing completion of this task, as the calculation of the combined probability of small-field inflation occurring together with a graceful exit into a minimum turned out to be more difficult than anticipated.

Moreover, in 2014 we saw the first detection of degree angular scale B-mode polarization in the cosmic microwave background radiation (CMB) by the BICEP2 telescope. Its potential implications for inflation happening at the GUT scale of grand unification, and hence the sensitivity to string theory effects, and then the reanalysis and joint analysis of the full temperature data from the Planck satellite and part of its own B-mode data showing unexpectedly strong dust foregrounds in our galaxy together with BICEP2 and its successor, the Keck Array, has driven a large burst of analysis and construction of large-field inflation models in string theory, many of them based on the mechanism of axion monodromy which the YIG group leader co-discovered in 2008. The members of the YIG consequently got strongly involved during 2014 in this process of analyzing the phenomenological range of string theory models of large-field inflation for B-mode production. This served the project well, as it showed that the landscape of large-field inflation models in string theory is significantly wider and varied than many anticipated earlier, and this needs now to be taken into account for the projects goal of analyzing the landscape of string inflation models. It is therefore foreseeable that, given these recent developments, a closure of the projects objectives may not be reachable by the project end in September 2015.

6) Status

Do you hold a joint Junior Professorship or a W2/W3 Professorship? Do you aim for such a position? What is the status of your negotiations in this respect?

I do not currently hold a joint Junior or W2/W3 Professorship. I have not yet decided on whether to pursue a potential professorship in the future.

7) Teaching Activities of the Group Leader

Summer semester 2014:

– Advanced Placement Course (APC-T) "Theoretical Astroparticle Physics and Cosmology" (4+2), Hamburg University, summer term 2014
http://www.desy.de/~westphal/cosmology_2014/cosmology.html

Winter semester 2014:

– Public talk (in German) in a series of 2 physics colloquia together with Dr. Torsten Ensslin at Hamburg University about "Kosmologie nach BICEP2 und Planck" on Dec 11, 2014
http://www3.physnet.uni-hamburg.de/VFFP/kolloquien.html

8) Publications of the Group

Papers:

1) "R^2 log R quantum corrections and the inflationary observables," I. Ben-Dayan, S. Jing, M. Torabian, A. Westphal & L. Zarate, JCAP **1409** (2014) 005 [arXiv:1404.7349]
2) "Hierarchical Axion Inflation," I. Ben-Dayan, F. G. Pedro & A. Westphal, Phys. Rev. Lett. **113** (2014) 261301 [arXiv:1404.7773]
3) "Chaotic Inflation in Supergravity after Planck and BICEP2," R. Kallosh, A. Linde & A. Westphal, Phys. Rev. D **90** (2014) 2, 023534 [arXiv:1405.0270]
4) "The Powers of Monodromy," L. McAllister, E. Silverstein, A. Westphal & T. Wrase, JHEP **1409** (2014) 123 [arXiv:1405.3652]
5) "Just enough inflation: power spectrum modifications at large scales," M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal, JCAP **1412** (2014) 12, 030 [arXiv:1407.1048]
6) "Towards Natural Inflation in String Theory," I. Ben-Dayan, F. G. Pedro & A. Westphal, arXiv:1407.2562
7) "Power Spectrum of Inflationary Attractors," B. Broy, D. Roest & A. Westphal, Phys. Rev. D **91** (2015) 2, 023514 [arXiv:1408.5904]
8) "String cosmology — Large-field inflation in string theory," A. Westphal, Int. Jour. Mod. Phys. A **30** (2015) 09, 1530024 [arXiv:1409.5350]
9) "Disentangling the f(R) - duality," B. Broy, F. G. Pedro & A. Westphal, JCAP **1503** (2015) 03, 029 [arXiv:1411.6010]
10) "Drifting Oscillations in Axion Monodromy," R. Flauger, L. McAllister, E. Silverstein & A. Westphal, arXiv:1412.1814

Talks (given by speaker):

1) Invited seminar talk at Hanover University, Hanover, Germany (January 2014) F. G. Pedro & A. Westphal: "Low-l CMB Power Loss in String Inflation"
seminar homepage

2) Invited talk at the workshop “Initial Conditions for Inflation”, PCCP, Paris, France (January 2014), M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal: “Low-l CMB Power Loss and String Inflation”
workshop homepage
3) Invited talk at the workshop “Quantum Gravity and Fundamental Cosmology”, AEI, Potsdam-Golm, Germany (March 2014), M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal: “Low-l CMB Power Loss and String Inflation”
workshop homepage
4) Invited talk at the workshop “Beyond the Standard Model”, Physikzentrum Bad Honnef, Bad Honnef, Germany (March 2014), M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal: “Pre-inflation and CMB power loss”
workshop homepage
5) Invited seminar talk at the University of New Hampshire, Durham, USA (March 2014), A. Westphal: “(String) Inflation after BICEP2”
6) Invited talk at the conference “The Particle Physics and Cosmology of Supersymmetry and String Theory”, New York City, USA (March 2014),
A. Westphal: “(String) Inflation after BICEP2”
conference homepage
7) Invited seminar talk at the Theory Seminar of the University of Bologna, Bologna, Italy (March 2014), M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal: “Pre-inflation and CMB power loss”
8) Invited talk at the workshop “IX Iberian cosmology meeting”, Aveiro, Portugal (April 2014), M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal: “Pre-inflation and CMB power loss”
workshop homepage
9) Invited review talk at the conference “String Phenomenology 2014”, Trieste, Italy (July 2014), A. Westphal: “String Cosmology - A Short Synopsis”
conference homepage
10) Invited talk at the conference “String Phenomenology 2014”, Trieste, Italy (July 2014), M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal: “Just enough inflation: power spectrum modifications on large scales”
conference homepage
11) Invited review talk at the International Symposium Ahrenshoop “On the Theory of Elementary Particles”, Berlin, Germany (August 2014), A. Westphal: “Large-Field Inflation – Naturalness and String Theory”
conference homepage
12) Invited review talk at the DESY theory workshop “Particle Cosmology after Planck”, Hamburg, Germany (September 2014), A. Westphal: “Inflation in String Theory: from small to large fields”
workshop homepage
13) Invited talk at the DESY theory workshop “Particle Cosmology after Planck”, Hamburg, Germany (September 2014), M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal: “Just enough inflation: power spectrum modifications on large scales”
workshop homepage
14) Invited talk at the DESY theory workshop “Particle Cosmology after Planck”, Hamburg, Germany (September 2014), B. Broy, D. Roest & A. Westphal: “The Power Spectrum of Inflationary Attractors”
workshop homepage
15) Invited talk at the DESY theory workshop “Particle Cosmology after Planck”, Hamburg, Germany (September 2014), D. Ciupke, J. Louis & A. Westphal: “Higher Derivative Supergravity and Implications for Moduli Stabilization and Inflation”
workshop homepage
16) Invited talk at the workshop “Fine-Tuning, Anthropics and the String Landscape”, Madrid, Spain (October 2014), J. Louis, M. Rummel, R. Valandro & A. Westphal: “Building an explicit de Sitter”

workshop homepage

17) Invited talk at the joint ERC workshop “Superfields, Selfcompletion and Strings & Gravity”, Munich, Germany (October 2014), F.G. Pedro & A. Westphal: “The scale of inflation in the landscape”
workshop homepage

18) Invited talk at the PCTP workshop “Open Questions in String Cosmology and Inflation”, Prince- ton, USA (October 2014), A. Westphal, L. McAllister & E. Silverstein: “Axion-Monodromy Inflation I: Overview”
workshop homepage

19) Invited talk at the conference “Indian Strings Meeting 2014”, Puri, India (December 2014), A. Westphal: “Large-field inflation - strings & pheno”
workshop homepage

9) External Funding

The YIG group leader has access to additional funds for travel and visiting scholars from the DFG Collaborative Research Center SFB 676 by virtue of being a PI for project C6.

10) Patent Applications

No. of pending/granted patents

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11) Awards received by Group Members / Professorship Appointments offered to Group Leader

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