

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:	01/2013-12/2013

1) Group Structure

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

Francisco Pedro, joined the group in October 2012. He did his PhD in the area of string cosmology under the supervision of Joseph P. Conlon at Oxford University, UK.

Markus Rummel, who was a PhD student in the YIG, having joined via the DFG Collaborative Research Center SFB 676, C6, in October 2010. He has finished his PhD in July 2013, and successfully acquired a postdoc position in the group of Joseph P. Conlon at Oxford University, UK, where he started October 2013. Markus Rummel was spending a 2-month invited visitor fellowship with Henry Tye and Gary Shiu at the Hongkong Institute for Advanced Study in April and May 2013.

Benedict Broy (Master at Hamburg U.) and David Ciupke (Master at Goettingen U.) have joined the YIG as PhD students in October 2013, starting on projects concerning the effects of non-minimal coupling to gravity on inflation, and higher superspace-derivative correction to the effective action of inflationary models.

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 close 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 2013 conference „String Phenomenology“

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

and 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 is one practical complaint I may have.

The first 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 be 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 that most of the e.g. US-based excellent postdocs factor such things into their decision on whether to accept an offer!)

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 (reached an important step towards the first major milestone):

Several of the published results in 2011 have enabled us in 2012 (arXiv: 1206.4034) to perform a first statistical analysis of the relative prevalences of large-field and small-field inflation in Calabi-Yau flux landscapes of type IIB string theory. These results have been presented in several talks in the US in 2012, have been published meanwhile in JHEP. They lead to two final, and complementary, mathematically well posed questions:

- 1) one aspect is the distribution of certain microscopic properties on the space of elliptically-fibered Calabi-Yau 4-fold compactifications of F-theory.
- 2) the other, complementary aspect concerns the statistics of accidentally arising saddle-point/inflection point regions of small-field inflation in the moduli potential of string compactifications.

(arXiv: 1303.3224) We were able to determine one main part of the answer to the 2nd question.

Its form implies an exponential statistical enhancement of number frequency small-field inflation over large-field inflation in the string landscape. Since it is known that the answer to question 1) can only yield a suppression of the number frequency of large-field models over small-field models of inflation in the landscape, in combination we reached a major step towards the first major milestone:

The statistical result for question 2) together with the structure of any possible answer to question 1) may lead to a statistical prediction of the expected level of primordial gravitational waves during inflation from an accessible and large part of the landscape of string theory – *provided* that we establish the joint probability of obtaining successful inflation *and* a graceful exit into a meta-stable dS vacuum of small vacuum energy.

By itself, the result in (arXiv: 1303.3224) might lead us to expect from string theory the absence of a primordial gravitational wave signal in the polarization of the cosmic microwave background (CMB) in current (such as the BICEP2 result) and the near-future observations. However, without knowing the joint probability of obtaining successful inflation *and* a graceful exit into a meta-stable dS vacuum of small vacuum energy, a prediction is invalid.

Concerning inflation model building in string theory constructions, we looked back at our explicit de Sitter construction from 2011 and 2012. There, we found that in variations of these constructions we can arrange for small model landscape of Kähler moduli driven small-field string inflation to occur (arXiv: 1309.0529).

In the context of flux-brane inflation, where the position of a moving D7-brane in type IIB string theory/F-theory acquires a slow-roll inflation scalar potential through turning on flux, we analyzed the resulting 2-field hybrid inflation potential. Since the axionic part of the D7-brane modulus is protected by a shift symmetry, the effective inflaton potential is of the form of hybrid inflation with a periodic cosine potential in the inflaton-axion direction – that is, we get “hybrid natural inflation” (axions with cosine potentials can drive what is called “natural inflation”). An analysis of this situation can provide for a tensor mode single $r > 0.001$ in mild violation of the generic Lyth bound (arXiv: 1305.1947).

Some of our most recent work focuses on the fact, that our existing observational evidence for inflation has access to just the last about 60 e-folds of inflationary expansion. We do not know, how much inflation our Universe underwent in total. However, if there was only the 55 .. 60 e-folds of 'just enough inflation' in our past, we may see this in form of deviations of the CMB temperature two-point function power spectrum for the slow-roll prediction of typical single-field inflation models. The PLANCK collaboration in 2013 has reported some evidence at the level of 2.5 -- 3 standard deviations. of exactly such an anomaly, namely that there is less CMB power on large angular scales $l < 50$ than predicted by a simple single-field slow-roll model. Such a power loss at low- l can occur if the slow-roll parameters start to change rapidly via steepening of the potential just at the beginning of our observable 60 e-folds of inflation, or if slow-roll breaks down there suddenly and entirely. We showed in very recent work (arXiv: 1309.3413), that there are models of inflation in string theory, such as fibre inflation in Calabi-Yau flux compactifications of type IIB string theory, where a power-loss at low- l arises rather naturally from the conditions of generating only the 60 e-folds of 'just enough inflation'.

Moduli stabilization in string theory:

As our de Sitter constructions in 2012 depend on the presence of perturbative quantum corrections, it was natural to enquire about the existence and consequences of possible further string quantum corrections on these classes of dS

vacua. Recently, Angelova et al. (2010) and Grimm et al. (2013) derived structurally similar corrections to the Kähler potential of the Calabi-Yau Kähler moduli at $O(\alpha'^2)$ in heterotic, and type IIB string theory, respectively. On the type IIB side (arXiv: 1306.1237) analyzed the effects of a similar $O(\alpha'^2)$ correction to the Kahler potential, leading to potentially strong constraints on the compactification volume and gravitino mass scale in all known models of type IIB moduli stabilization in dS vacua. These constraints may impact significantly on the type IIB constructions of low-energy phenomenology and cosmological inflation.

(arXiv: 1304.1809) Here, we perform a systematic analysis of moduli stabilization for weakly coupled heterotic string theory compactified on smooth Calabi-Yau three-folds in models with (0,2) worldsheet supersymmetry. After reviewing how to stabilise all the geometric moduli in a supersymmetric way by including fractional fluxes, non-perturbative and threshold effects, we show that the inclusion of α' -corrections leads to new de Sitter or nearly Minkowski vacua which break supersymmetry spontaneously. The minimum lies at moderately large volumes of all the geometric moduli, at perturbative values of the string coupling and at the right phenomenological value of the grand-unified (GUT) gauge coupling. However the structure of the heterotic 3-form flux used for complex structure moduli stabilization does not contain enough freedom to tune the superpotential. This results in the generic prediction of GUT-scale supersymmetry breaking. We finally provide a dynamical derivation of anisotropic compactifications with stabilized moduli which allow for perturbative gauge coupling unification around 10^{16} GeV.

Finally, we closed 2013 with a thorough study of moduli spaces in AdS_4 supergravity, both with $N = 1$ and $N = 2$ supergravity. The connection of such moduli spaces, which are non-generic in AdS_4 space-time, is connected to (sometimes accidental) global symmetries, most commonly a shift symmetry. As such, statements about moduli spaces in AdS_4 , being the precursor to de Sitter vacua in string theory, are potentially relevant for models of inflation in string theory.

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 concerning the timeline which was initially set out.

We reached an important *step towards the first major milestone* of the project in 2013: Our results in (arXiv: 1206.4034) and (arXiv: 1303.3224) contain a statistical enhancement of the number frequency of small-field models from string over large-field models.

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

winter semester 2012/2013:

- Postgraduate Level Course “Theoretical Cosmology” (3+1), Hamburg University, winter term 2012/2013
http://www.desy.de/~westphal/cosmology_2012/cosmology.html
- Wolfgang-Pauli-Centre Blackboard Seminar: “From Inflation to the Landscape Multiverse”, DESY, Hamburg, Germany, February 2013

<https://indico.desy.de/conferenceDisplay.py?confId=6868>

- lecture on “Aspects of Inflationary Cosmology”, XXV Workshop Beyond the Standard Model, Bad Honnef, Germany, March 2013

<https://indico.desy.de/sessionDisplay.py?sessionId=15&confId=6988#20130320>

8) Publications of the Group

Papers:

- 1) “The Scale of Inflation in the Landscape,” F. G. Pedro & A. Westphal, arXiv:1303.3224
- 2) “Heterotic Moduli Stabilization,” M. Cicoli, S. de Alwis & A. Westphal, JHEP **1310** (2013) 199 [arXiv:1304.1809]
- 3) “Evading the Lyth Bound in Hybrid Natural Inflation,” A. Hebecker, S. Kraus & A. Westphal, Phys. Rev. D **88** (2013) 123506 [arXiv:1305.1947]
- 4) “Extended No-Scale Structure and α^2 Corrections to the Type IIB Action,” F. G. Pedro, M. Rummel & A. Westphal, arXiv:1306.1237
- 5) “Moduli destabilization via gravitational collapse,” D.-i. Hwang, F. G. Pedro & D.-h. Yeom, JHEP **1309** (2013) 159 [arXiv:1306.6687]
- 6) “Accidental inflation from Kähler uplifting,” I. Ben-Dayan, S. Jing, A. Westphal & C. Wieck, JCAP **1403** (2014) 054 [arXiv:1309.0529]
- 7) “Low- ℓ CMB power loss in string inflation,” F. G. Pedro & A. Westphal, JHEP **1404** (2014) 034 [arXiv:1309.3413]
- 8) “On Moduli Spaces in AdS₄ Supergravity,” S. de Alwis, J. Louis, L. McAllister, H. Triendl & A. Westphal, *accepted for publication in JHEP*, [arXiv:1312.5659]

Talks (given by speaker):

- 1) “Building an explicit de Sitter”, J. Louis, M. Rummel, R. Valandro & A. Westphal, invited talk, CERN string theory seminar, Geneva, CERN, January 2013
[workshop homepage](#)
- 2) “Building an explicit de Sitter vacuum in string theory”, J. Louis, M. Rummel, R. Valandro & A. Westphal, invited seminar talk at Padova University, Padova, Italy, February 2013
[workshop homepage](#)
- 3) “Tensors in the landscape”, F. Pedro & A. Westphal, invited seminar talk, Rencontres Theoriciennes, Paris, France, March 2013
[workshop homepage](#)
- 4) “Construction of explicit de Sitter vacua in type IIB flux compactifications”, J. Louis, D. Martinez-Pedrerera, D. Mehta, M. Rummel, R. Valandro & A. Westphal, invited talk, XXV Workshop Beyond the Standard Model, Bad Honnef, Germany, March 2013
[workshop homepage](#)
- 5) “Explicit complex structure moduli stabilization in IIB flux compactifications”, J. Louis, D. Martinez-Pedrerera, D. Mehta, M. Rummel, R. Valandro & A. Westphal, invited talk, International Research Program “The Particle Physics and Cosmology of Supersymmetry and String Theory” workshop “New Developments in Gravity, Cosmology and Strings”, Munich, Germany, March 2013
[workshop homepage](#)
- 6) “Inflation in the Wigner landscape”, F. Pedro & A. Westphal, invited talk, International Research Program “The Particle Physics and Cosmology of Supersymmetry and String Theory” workshop “New Developments in Gravity, Cosmology and Strings”, Munich, Germany, March 2013
[workshop homepage](#)
- 7) “Tensors in the landscape”, A. Westphal, invited talk, International Research Program “The Particle Physics and Cosmology of Supersymmetry and String Theory” workshop “New Developments in Gravity, Cosmology and Strings”, Munich, Germany, March 2013

<p>workshope homepage</p> <p>8) “Inflationary cosmology after Planck”, A. Westphal, invited talk, International Research Program “The Particle Physics and Cosmology of Supersymmetry and String Theory” workshop “New Developments in Gravity, Cosmology and Strings”, Munich, Germany, March 2013</p> <p>workshope homepage</p> <p>9) “Inflationary in the Wigner Landscape”, F. G. Pedro & A. Westphal, invited talk, International Research Program “The Particle Physics and Cosmology of Supersymmetry and String Theory” workshop “New Developments in Gravity, Cosmology and Strings”, Munich, Germany, March 2013</p> <p>workshope homepage</p> <p>10) “Heterotic moduli stabilization”, S. de Alwis, M. Cicoli & A. Westphal, invited seminar talk, Stanford University, Palo Alto, USA, May 2013</p> <p>11) “Extended no-scale structure and α^2-corrections to the type IIB action”, F. G. Pedro, M. Rummel & A. Westphal, invited talk, PLANCK 2013 conference, Bonn, Germany, May 2013</p> <p>workshope homepage</p> <p>12) “Inflationary Ramifications of a Meta-Stable Higgs Vacuum”, O. Lebedev & A. Westphal, invited talk, forum “Higgs Meta-Stability Forum”, DESY, Hamburg & Berlin, Germany, June 2013</p> <p>workshope homepage</p> <p>13) “Tensors in the Landscape ...”, A. Westphal, invited seminar talk, Goettingen University, Germany, June 2013</p> <p>workshope homepage</p> <p>14) “Tensors in the Landscape ...”, A. Westphal, invited seminar talk, ICTP, Trieste, June 2013</p> <p>workshope homepage</p> <p>15) “Extended no-scale structure and α^2-corrections to the type IIB action”, F. G. Pedro, M. Rummel & A. Westphal, invited talk, SUSY 2013 conference, ICTP, Trieste, August 2013</p> <p>workshope homepage</p> <p>16) “Inflation in the Wigner Landscape”, F. G. Pedro & A. Westphal, invited talk, COSMO 2013 conference, Cambridge, UK, September 2013</p> <p>workshope homepage</p> <p>17) “Low-ℓ CMB power loss in string inflation”, M. Cicoli, S. Downes, B. Dutta, F. G. Pedro & A. Westphal, invited talk, Groningen, Netherlands, Nov 2013</p> <p>workshope homepage</p>
<p>9) External Funding</p> <p>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.</p>
<p>10) Patent Applications</p> <p><i>No. of pending/granted patents</i></p> <p>...</p>
<p>11) Awards received by Group Members / Professorship Appointments offered to Group Leader</p>

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