

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:	01/2012-12/2012

1) Group Structure

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

Pascal Vaudrevange, who initially joined the group in October 2010, has completed his quite successful postdoc in September 2012. He left the group with a successful offer from the private sector.

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

It continues to prove difficult to find further PhD students which fit the profile of the group: A candidate needs to combine sufficient mathematical training and knowledge in courses like advanced quantum field theory and general relativity, and an interest in more speculative theoretical work (i.e. not as closely connected to potential data as, say, SUSY phenomenology for the LHC), and this without being too strongly formal (as this can hinder the transfer of results and intuition due to the considerably different language used in the formal/pure mathematics, and theoretical physics). Such candidates are not easy to find – Markus Rummel was a lucky and excellent (!) coincidence so far (in particular in the wider German area; PhD candidates from, say, the US, where the combination of training and interests discussed is more easily found, are not easily wooed to take the transition to Europe).

At this time the YIG is conducting interviews with a possible PhD candidate. This selection process should be finished by the end of June 2013.

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 2012 workshop “Implications of the Early LHC for Cosmology”:

<https://indico.desy.de/conferenceDisplay.py?confId=5231>

at DESY, and is co-organizing the 2013 conference „String Phenomenology“ here 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 quite 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 text books, computing hardware etc). 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. This can lead to considerable delays, and has in my case, prevented me from providing my first postdoc in 2010 with a laptop computer for work (given the frequent travel to conferences a laptop is just plainly practical). The theory group has remedied this meanwhile as a whole, by providing theory postdocs in general with access to DESY laptop computers – but it is not clear why this was blocked in the first place, and needed to be approved by the central DESY administration at all (as long as the Helmholtz-funded part of the YIG is concerned).

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 first major milestone):

(arXiv:1202.2721) In this paper and a prequel from fall 2011 we calculated, together with Koushik Dutta, Cecelie Hector, Pascal Vaudrevange, and Thomas Konstandin, the first new exact tunneling solution with exact and explicit expression for the tunneling action integral $B = S_E(\phi) - S_E(\phi_0)$ in flat space, since the piecewise-linear potential solution by Duncan & Jensen in 1992, and the influence on tunneling by kinks in the potential energy of a scalar field which can arise in leading-order treatments of string theory solutions.

(arXiv:1205.1663) With Pascal Vaudrevange we constructed a simple purely polynomial potential for a single scalar field consistent with effective field theory requirements and arising generically in certain sectors of string compactifications, which gave a model of open slow-roll inflation following a Coleman-DeLuccia tunneling transition from high-lying false vacuum which is part of the same potential. The model demonstrated explicitly in a full example the absence of overshoot on the inflationary plateau after tunneling due to the curvature inside the nucleated bubble, thus displaying a general result about the avoidance of overshoot after tunneling published by the YIG in 2011.

(arXiv: 1206.4034) Several of the published results in 2011 have enabled us now 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.

Inflation & phenomenology:

(arXiv: 1210.6987) Here we looked at the cosmological implications of the 2012 discovery of a Higgs boson with 126 GeV mass at the LHC in the context of the stability of the electro-weak vacuum of the pure Standard Model (SM) of particle physics. If the LHC results as well as the measurements of the top quark mass tighten down at the same central values in the future, then the electro-weak symmetry breaking vacuum might get confirmed to be meta-stable under quantum-mechanical vacuum decay into anti-de-Sitter (AdS) space (the evidence for meta-stability is around 3-sigma confidence level at this time). Furthermore, in this case the electro-weak vacuum would suffer rapid vacuum instability during the phase of early cosmological inflation from inflationary quantum fluctuations. If this is case, we showed from simple effective field theory arguments that one should expect a small but potentially relevant *direct cross-coupling* between the inflaton scalar field and the Higgs field, which stabilizes the electro-weak vacuum during inflation. This Higgs-inflaton cross-coupling may be potentially measurable.

(arXiv: 1211.0070) Primordial non-Gaussianity of the quantum fluctuations generated during inflation became an important theoretical tool in the last half decade, as the momentum-space distribution of the 3-point function of the fluctuations, the 'shape', may discriminate between many different classes of inflationary models. We showed that a certain shape of non-Gaussianity (equilateral) typically associated with the presence of higher-derivative corrections during inflation can be obtained by single-field inflation models without higher-derivative terms

if they have periodic corrections to their overall scalar potential. This demonstrated a degeneracy in the non-Gaussian observable which previously was assumed to discriminate between these inflation model classes. Knowledge about such degeneracies may become even more important given the strength of the recent PLANCK satellite's constraints on non-Gaussianity.

Moduli stabilization in string theory:

(arXiv: 1208.3208) One highlight of the project consists in the successful construction of a set of explicit de Sitter vacua realizing the mechanism of 'Kähler uplifting' in both type IIB string theory and its non-perturbative F-theory limit based on a leading-order quantum correction from type IIB string theory. This is one of the few existing manifestly supersymmetric string compactifications with complete moduli stabilization where the breaking of supersymmetry in a dS state occurs entirely within the framework of spontaneously broken F-term supergravity.

(arXiv: 1212.4530) Having an explicit construction in hand furthermore was key for an explicit study of the 'discretuum' of flux vacua – the local 'landscape' – generated by scanning over the quantized values of the higher p-form fluxes of type IIB string theory. The resulting vacuum statistics for e.g. the minimal spacing of values of the cosmological constant or the gravitino mass scale of supersymmetry breaking verified for this non-trivial example general approximative analytical results in the extant literature.

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 year 2012 shows a slight deficit of 12780.49 € which is due to certain details of the DESY-internal budgeting process. This deficit will be foreseeably compensated for in 2013.

The project is on track concerning the timeline which was initially set out.

We meanwhile reached the *first major milestone* of the project in 2013: Our results in (arXiv: 1206.4034) and (arXiv: 1303.3224) contain a statistical prediction from string theory that we expect the absence of a primordial gravitational wave signal in the polarization of the cosmic microwave background (CMB) in the near future (e.g. the PLANCK satellite polarization data release in 2014, and upcoming ground-based data such as from KECK array at the south pole).

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
- lectures on "Aspects of Inflationary Cosmology", XXIX Heidelberg Physics Graduate Days of the Heidelberg Graduate School of Fundamental Physics and the Department of Physics, Heidelberg, Germany, October 2012
http://gsfp.physi.uni-heidelberg.de/graddays_oktober_2012/

8) Publications of the Group

Papers:

- 1) "On the Existence of Tunneling Bounce Solutions in Piecewise Linear Potentials", K. Dutta, C. Hector, T. Konstandin, P.M. Vaudrevange & A. Westphal, Phys. Rev. D **86**, (2012) 123517 [arXiv:1202.2721]
- 2) "A Toy Model For Single Field Open Inflation", P.M. Vaudrevange & A. Westphal, arXiv:1205.1663
- 3) "Tensor modes on the string theory landscape," A. Westphal, JHEP **1304** (2013) 054 [arXiv:1206.4034]
- 4) "Building an explicit de Sitter," J. Louis, M. Rummel, R. Valandro & A. Westphal, JHEP **1210** (2012) 163 [arXiv:1208.3208]
- 5) "Metastable Electroweak Vacuum: Implications for Inflation," O. Lebedev & A. Westphal Phys. Lett. B **719**, 415 (2013) [arXiv:1210.6987]
- 6) "Resonant non-Gaussianity with equilateral properties," R. Gwyn, M. Rummel & A. Westphal, arXiv:1211.0070
- 7) "Finding all flux vacua in an explicit example," D. Martinez-Pedrerera, D. Mehta, M. Rummel & A. Westphal, arXiv:1212.4530
- 8) "The Scale of Inflation in the Landscape," F. G. Pedro & A. Westphal, arXiv:1303.3224

Talks (given by speaker):

- 1) "A sufficient condition for IIB/F-theory dS vacua", M. Rummel & A. Westphal, Nordic String Theory Meeting 2012, Copenhagen, Denmark, February 2012
<https://indico.nbi.ku.dk/conferenceTimeTable.py?confId=397#all>
- 2) "Tensors in the landscape", A. Westphal, invited seminar talk, Stanford University, USA, February 2012
<http://www.stanford.edu/group/sitp/SITP%20Seminar%20Table.htm>
- 3) "Inflation and the Landscape of String Theory", A. Westphal, invited seminar talk, SETI institute, Mountain View, California, USA, February 2012
<http://www.seti.org/weekly-lecture/inflation-and-landscape-string-theory-0>
<http://www.youtube.com/watch?v=t2Ov6KNZ7-Y>
- 4) "Tensors in the landscape", A. Westphal, invited seminar talk, UC Berkeley, USA, February 2012
http://www-theory.lbl.gov/cgi-bin/talks/plans.cgi?cal_id=0&cal_start_month=2&cal_start_year=2012
- 5) "The Overshoot Problem in Inflation after Tunneling", K. Dutta, P.M. Vaudrevange & A. Westphal, Beyond the Standard Model 2012, Bad Honnef, Germany, March 2012
<http://www.desy.de/uni-th/stringth/bad-honnef/2012/>
- 6) "A sufficient condition for IIB/F-theory dS vacua", M. Rummel & A. Westphal, Beyond the Standard Model 2012, Bad Honnef, Germany, March 2012
<http://www.desy.de/uni-th/stringth/bad-honnef/2012>
- 7) "Tensors in the landscape", A. Westphal, invited talk, The Particle Physics and Cosmology of Supersymmetry and String Theory, Philadelphia, USA, March 2012
http://www.physics.upenn.edu/Int_L_program/agenda.html
- 8) "A sufficient condition for de Sitter vacua in type IIB string theory", J. Louis, M. Rummel, R. Valandro & A. Westphal, invited talk, Brane backreaction, fluxes and meta-stable vacua in string theory, Uppsala, Sweden, May 2012
<http://www.physics.uu.se/teorfys/en/content/brane-backreaction-fluxes-and-meta-stable-vacua-string-theory-may-2-4-2012>
- 9) "De Sitter vacua in type IIB / F-theory by Kahler uplifting", J. Louis, M. Rummel, R. Valandro & A. Westphal, invited talk, String Phenomenology 2012, Cambridge, United Kingdom, June 2012
<http://www.newton.ac.uk/programmes/BSM/bsmw05.html>

- 10) "Tensors models on the string theory landscape", A. Westphal, invited talk, String Phenomenology 2012, Cambridge, United Kingdom, June 2012
<http://www.newton.ac.uk/programmes/BSM/bsmw05.html>
- 11) "Towards explicit de Sitter vacua", J. Louis, M. Rummel, R. Valandro & A. Westphal, invited talk, The 3rd UTQuest workshop ExDiP 2012 Superstring Cosmophysics, Obihiro, Japan, August 2012
<http://research.kek.jp/people/hkodama/ExDiP2012/Site/Home.html>
- 12) "Tensors in the Landscape", A. Westphal, invited talk, The 3rd UTQuest workshop ExDiP 2012 Superstring Cosmophysics, Obihiro, Japan, August 2012
<http://research.kek.jp/people/hkodama/ExDiP2012/Site/Home.html>
- 13) "Building an explicit de Sitter", J. Louis, M. Rummel, R. Valandro & A. Westphal, invited talk, SISSA/ISAS Theoretical Particle Physics Group Seminar, Trieste, Italy, September 2012
<http://www.sissa.it/tpp/activity/wedseminar.php>
- 14) "Building an explicit de Sitter", J. Louis, M. Rummel, R. Valandro & A. Westphal, invited talk, 4th Bethe Center Workshop on Unification and String Theory, Bonn/Bad Honnef, Germany, October 2012
<http://www.thphys.uni-heidelberg.de/~weigand/seminar.html>
- 15) "De Sitter vacua in type IIB string theory / F-theory by Kahler uplifting", J. Louis, M. Rummel, R. Valandro & A. Westphal, invited talk, seminar "String Theory and Beyond the Standard Model" at the Institute for Theoretical Physics, Heidelberg, October 2012
<http://www.newton.ac.uk/programmes/BSM/bsmw05.html>
- 16) "Building an explicit de Sitter", J. Louis, M. Rummel, R. Valandro & A. Westphal, invited talk, CERN string theory seminar, Geneva, CERN, January 2013
<http://indico.cern.ch/conferenceDisplay.py?confId=208489>

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

...

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

...