Final Report

Strong Coupling and Holography in Cosmology
November 7th & 8th 2011

1 Summary

This workshop explored the possible role of strongly coupled physics, and possibly its description in terms of holography, in inflationary cosmology. There are (at least) three different ways that strong coupling physics may play a role in inflationary cosmology. Firstly, the inflaton could be a composite particle of a strongly interacting theory which however still has an effective weakly coupled description at low energies, with its properties (potential etc.) originating from underlying strongly interacting theory. Secondly, the inflaton sector could be strongly coupled but with gravity itself still having a conventional description (Einstein gravity). Thirdly, the very early universe may have been in a strong coupled non-geometric phase with no conventional gravitational description at all till late times (with late meaning the end of this era, which is the beginning of hot big bang cosmology). In all three cases holography may provide an alternative useful description by either mapping the strong coupling QFT problem to a weakly coupled gravitational one in one dimension higher (first two cases) or by providing a weakly coupled QFT description in one dimension less (last case). All three approaches have been presented in this workshop.

2 Scientific content

It is currently believed that the very early universe undergone a phase of rapid acceleration, the so-called inflationary epoch. The simplest inflationary models involve gravity weakly coupled to a scalar field that slowly rolls down its potential. These models lead to a nearly scale invariant spectrum of primordial fluctuations and very small (unobservable) non-Gaussianity. Many other (more complicated) inflationary models, still perturbative in nature, (involving higher derivative terms, many fields etc.) have been considered in the literature and their observational signatures have been mapped out. There is, however, no reason why the theory of inflation should be perturbative. Moreover conventional models have many unsatisfactory features (fine-tuning, trans-Planckian issues etc.). In the last year a number of groups have begun to explore the role that strong interactions and holography could play in cosmology and the aim of this workshop was to bring them together

to discuss the different approaches.

Since elementary scalar fields have yet to be observed in Nature, one may wonder whether the inflaton could be a composite particle of a strongly interacting theory. At low energies such theory could still have a conventional description in terms of an effective scalar field weakly coupled to gravity. However, the properties of the effective scalar (its potential etc.) would follow from the underlying strongly interactive theory. Such a model was presented in this workshop by Sannino. Holography could play a role here by providing explicit calculable examples where the properties of the scalar sector are obtained holographically via gravitational computations in one dimension higher. A realization using AdS/CFT and probe branes was discussed by Evans. Servant and Konstantin presented related work on the implications of such scenarios on baryogenesis and the construction of Randall-Sundrum type models based on warped compactifications.

The inflaton sector could be strongly coupled but with gravity itself still having a conventional description in terms of Einstein gravity. At the point where the effective description breaks down one expects to find "new physics". A prototype example is the standard model without the Higgs boson. The low energy effective description of Z and W bosons becomes strongly coupled around 1 TeV and one expects new physics to become important then. The analogous situation in the context of inflationary cosmology was addressed in the talk by Green. A strongly coupled inflaton QFT may have a weakly coupled holographic dual. Such models may be constructed in string theory as warped compactifications with AdS throats modeling the inflaton sector (strongly coupled CFT). This was discussed by Chen.

The very early universe may have been non-geometric with no conventional gravitational description at all till late times (with late meaning the end of this era, which is the beginning of hot big bang cosmology). In such models the entire system may be described holographically via a perturbative three dimensional QFT (no gravity) and have no useful gravitational description (it should have a description in string theory as a strongly coupled sigma model). The predictions of a class of such models are compatible with current observations, yet they are distinct from those of conventional (slow-roll) inflation. This has been discussed by McFadden. The QFT involved in these descriptions is related at the perturbative level by a certain analytic continuation to conventional QFT and a question addressed in this workshop was whether one can construct examples of such duality that hold non-perturbatively (talk by Anninos) or explain the analytic continuation using a Hartle-Hawking type construction (talk by Hertog).

3 Assessment

This was a very successful workshop with over 40 participants. The original estimate of 10-20 participants was superseded by the interest expressed by the community. Several experts flew to Amsterdam from the USA just for this workshop. This is a unique circumstance where the latest theoretical ideas may be directly confronted with data in the very near future (the results from the Planck satellite are expected to be released by the end of this year) and as such this was also a timely workshop. This workshop led to a better understanding of the several approaches on the possible relevance of strong coupling physics and holography to cosmology.

Annex 1: Programme of the meeting

Monday, November 7		
09:30 - 10:30	Evans	Holography of a Composite Inflaton
10:30 - 11:00	Coffee break	
11:00 - 12:00	Anninos	Future infinity, solipsism and de Sitter holography
12:00 - 14:00	Lunch break	
14:00 - 15:00	Sannino	Composite Inflation
15:00 - 15:30	Coffee break	
15:30 - 16:30	Servant and Konstandin	A strong-first order phase transition at the EW scale and its cosmological consequences
Tuesday, November 8		
09:30 - 10:30	Green	Strong Coupling and the EFT of Inflation
10:30 - 11:00	Coffee break	
11:00 - 12:00	McFadden	Holographic cosmology
12:00 - 14:00	Lunch break	
14:00 - 15:00	Chen	Strongly coupled inflaton
15:00 - 15:30	Coffee break	
15:30 - 16:30	Hertog	Euclidean Eternal Inflation

Annex 2: List of Participants

1	Kostas Skenderis	University of Amsterdam	Convenor
2	Dionysios Anninos	Stanford University	Speaker
3	Xingang Chen	Cambridge University	Speaker
4	Nick Evans	Southampton University	Speaker
5	Daniel Green	IAS	Speaker
6	Thomas Hertog	Leuven University	Speaker
7	Thomas Konstandin	CERN	Speaker
8	Paul McFadden	Perimeter Institute	Speaker
9	Francesco Sannino	CP3-Origins	Speaker
10	Geraldine Servant	CERN	Speaker
11	Adam Bzowski	University of Amsterdam	Participant
12	Ricardo Caldeira Costa	University of Amsterdam	Participant
13	Borun Chowdhury	University of Amsterdam	Participant
14	Geoffrey Compere	University of Amsterdam	Participant
15	Ben Craps	Vrije Universiteit Brussel	Participant
16	Mafalda Dias	University of Sussex	Participant
17	Chialva Diego	University of Mons	Participant
18	Raphael Flauger	IAS	Participant
19	Tom Hartman	IAS	Participant
20	Michal Heller	University of Amsterdam	Participant
21	Juan Jottar	University of Amsterdam	Participant
22	Keun-Young Kim	University of Amsterdam	Participant
23	Elias Kiritsis	University of Crete	Participant
24	Yegor Korovin	University of Amsterdam	Participant
25	Manuela Kulaxizi	Universite libere de Bruxelles	Participant
26	Sander Mooij	University of Amsterdam	Participant
27	Ali Naseh	University of Amsterdam	Participant
28	Francesco Nitti	APC	Participant
29	Johannes Oberreuter	University of Amsterdam	Participant
30	Enrico Pajer	Princeton University	Participant
31	Andrei Parnachev	Leiden University	Participant
32	Marieke Postma	University of Amsterdam	Participant
33	Jan Pieter Schaar van der	University of Amsterdam	Participant
34	Wilke Schee van der	Utrecht University	Participant
35	Bert Schellekens	Nikhef	Participant
36	Jan Smith	University of Amsterdam	Participant
37	Milena Smolic	University of Amsterdam	Participant
38	Jelena Smolic	University of Amsterdam	Participant
39	Marika Taylor	University of Amsterdam	Participant
40	Benjamin Withers	Durham University	Participant
41	Bram Wouters	University of Amsterdam	Participant