

# Scientific Report on HoloGrav 2014 - “Holographic Methods and Applications”

## 1. Summary

The 2014 annual meeting of the ESF network HoloGrav was held on the campus of the University of Iceland in Reykjavík on August 18-22, 2014.

The workshop focused on recent results and ongoing research involving the holographic principle and its applications. It brought together scientists working on different aspects of holography, creating a fruitful environment for open discussion encouraging new scientific collaborations in theoretical physics.

- Scientific organizing committee:  
Johanna Erdmenger (MPI, Munich)  
Valentina Giangreco Puletti (Univ. of Iceland)  
Esko Keski-Vakkuri (Helsinki Univ.)  
Elias Kiritsis (Univ. of Crete)  
Joseph Minahan (Uppsala Univ.)  
Niels Obers (NBI, Copenhagen)  
Lárus Thorlacius (Nordita & Univ. of Iceland)

There were 76 participants, of whom 73 came from member and associated countries of the network. A total of 20 invited and 24 contributed talks were given (see Section 4 below). The main topics discussed at the workshop were:

- quantum entanglement
- out of equilibrium dynamics in condensed matter and in heavy ion collisions
- explicit and spontaneous symmetry breaking in holographic models
- holography for higher spin theories
- integrability in supersymmetric gauge theories

The complete workshop program can be found at the website <http://agenda.albanova.se/conferenceDisplay.py?confId=4191>

## 2. Description of the scientific content of and discussions at the event

Since its discovery by Maldacena in 1997, gauge/gravity duality (also referred to as holographic duality) has brought about a major shift of viewpoint in string theory and theoretical high-energy physics. The conjectured correspondence between strongly (weakly) coupled gauge theories and weakly (strongly) coupled strings on a higher dimensional curved background, has not only led to important developments in the investigation of fundamental interactions of matter but also given rise to unexpected applications across different fields of theoretical physics. The duality provides us with a powerful set of non-perturbative techniques to investigate non-trivial quantum field

theories. The best-established example, in this respect, is the full solvability of planar maximally supersymmetric Yang-Mills theory in four dimensions due to its underlying integrability. There are also more applied facets to holographic duality, extending the original conjecture to models with reduced supersymmetry (or no supersymmetry at all) and computing observables that can be compared to measurements in certain strongly coupled physical systems.

The meeting was focused on both the formal and more applied directions of research involving holographic duality. On the applied side, the goal is to address within the holographic framework a number of challenging problems involving strong correlations that arise in condensed matter physics and/or heavy-ion, quark-gluon plasma physics, and which have proved resistant to more conventional perturbative quantum field theory approaches. The talks on holographic applications introduced new models designed to modes specific field theoretic systems but also discussed some rather general bulk gravity mechanisms giving rise to interesting quantum behavior that can be realized across a range of different applications. Several themes were discussed at the meeting:

- AdS/QCD, that is gauge/gravity duality applied to Quantum Chromo Dynamics (QCD): At the meeting top-down holographic models were presented that are able to describe certain mesonic spectra, which can be successfully compared with numerical data from lattice gauge theory. Also, results from bottom-up approaches were reported, especially in the so-called Veneziano limit, where the number of colors and the number of matter flavors are taken to be very large but their ratio is kept fixed. In this regime it has been possible to construct models incorporating gravitational back-reaction to study finite temperature effects as well as re-produce certain QCD-like properties.
- AdS/CMT, that is applications of holography to condensed matter physics: This is a rather large sub-area. Among the results presented at the workshop were holographic models engineered to describe strongly coupled phenomena including the Kondo effect, the Quantum Hall effect, superfluidity, quantum critical systems, and non-Fermi liquids. Another important issue in AdS/CMT concerns the implementation of lattice structures into holographic models and the study of transport properties.

Concerning more fundamental aspects of the duality, much effort has gone into identifying possible generalizations of Maldacena's original duality, including ones involving reduced supersymmetry. This is particularly important in view of the fact that supersymmetry has so far not been observed in experiments. Themes present at the conference included:

- New gauge/gravity dualities: Lower dimensional examples of AdS/CFT where the gravity side is under good control (the bulk geometry and the corresponding string realization are known) but relatively little is known about the dual field theory directly. Results going in the "opposite" direction were also presented, that is the construction of a gravity dual to a known two-dimensional conformal field theory.
- Entanglement measures and holography: This is a very active field of research. Talks were mainly focused on understanding the meaning of entanglement from a holographic perspective (for instance the relation between entanglement and wormhole

geometries) and on proposals for suitable entanglement measures for mixed states from a field theory point of view.

- Holographic renormalisation: The study of renormalization group flow in holography is crucial not only in view of developing applications but also to investigate the (in-)stability of certain geometries. Analytic and numerical results were reported in several talks.
- Higher spin holography: A very different example of gauge/gravity duality has emerged in recent years where vector models are conjectured to be dual to higher spin gravity theories in AdS backgrounds. At the meeting recent results were reviewed on testing this type of duality in various spacetime dimensions.
- Non-relativistic fluid/gravity correspondence and Lifshitz space-time: Asymptotically Lifshitz geometry realizes scaling symmetries, which naturally appear in many non-relativistic systems, including quantum critical theories in condensed matter physics. Developing a better understanding of the symmetries of these space-time geometries and their corresponding boundary field theories is of central importance, and progress in this direction was reported in several talks at the meeting.
- Spin matrix models, integrability, and conformal bootstrap: Another theme at the meeting involved solvable field theories and constraints obtained from conformal symmetry. There were talks summarizing the state-of-art concerning the solvability of supersymmetric Yang-Mills theory (SYM) in the planar limit as well as more general conformal field theories. Moreover, new models were presented which emerge from certain decoupling limits of SYM and are able to encode interesting new physics.

### **3. Assessment of the results and impact of the event on the future directions of the field**

The conference succeeded in bringing together scientists from different fields of theoretical physics that border on gauge theory/gravity duality and its applications. A lively atmosphere for discussion and further collaboration was achieved thanks to the strong engagement by speakers and active participation by the conference audience. In addition to experts on gravitational theory working in the area of holography, the meeting was attended by condensed matter physicists who presented their point of view on major open issues within applied holography. This has led to very active discussions and a positive exchange of ideas that will help to identify promising new avenues to explore in this very active area of research.

### **4. Final Programme of the meeting**

There were 20 invited 45-minute talks and 24 contributed 30 minute talks:

- Invited speakers:  
Timo Alho, University of Jyväskylä  
Alejandra Castro, University of Amsterdam  
Miguel Costa, University of Porto

Ben Craps, Vrije Universiteit Brussels  
Aristomenis Donos, DAMTP, Cambridge  
Johanna Erdmenger, MPI, Munich  
Nick Evans, University of Southampton  
Jerome Gauntlett, Imperial College  
Simone Giombi, Princeton University  
Blaise Goutéraux, Nordita  
Andrew Green, University College London  
Giuseppe Policastro, ENS  
Simon Ross, Durham University  
Koenraad Schalm, Leiden University  
David Tong, DAMTP, Cambridge  
Erik Tonni, SISSA  
Stefan Vandoren, Utrecht University  
Balt Van Rees, CERN  
Dmytro Volin, Trinity College Dublin  
Jan Zaanen, Leiden University

- Contributed talks by:

Daniel Arean, University of Crete  
Andrey Bagrov, Leiden University  
Yago Bea Besada, University of Santiago de Compostela  
Marko Djuric, Porto University  
Antón Faedo, University of Barcelona  
Daniel Fernandez, University of Crete  
Michael Gary, Institute of Theoretical Physics, Vienna University of Technology  
Gianluca Grignani, University of Perugia  
Troels Harmark, Niels Bohr Institute  
Jelle Hartong, Niels Bohr Institute  
Carlos Hoyos Badajoz, Tel Aviv University  
Maria Irakleidou, Institute of Theoretical Physics, Vienna University of Technology  
Matti Jarvinen, University of Crete  
Alexander Krikun, Nordita  
Matthew Lippert, University of Amsterdam  
Daniele Musso, ICTP  
Dmitry Ponomarev, Ludwig Maximilian University  
Razieh Pourhasan, Univ. of Iceland & Perimeter Institute  
Christopher Rosen, University of Crete  
Javier Tarrio, University of Barcelona  
Benjamin Withers, University of Southampton  
Tobias Zingg, ITF Utrecht.

The complete list of abstracts can be found at  
<http://agenda.albanova.se/conferenceProgram.py?confId=4191>

## 5. List of participants

There were 76 participants at the workshop, of whom 73 came from member and associated countries of the network.

### NAME and COUNTRY

Dr. ALBRECHT, Dylan - GREECE  
Dr. ALHO, Timo - FINLAND  
Dr. AMADO, Irene - ISRAEL  
Mr. ARAUJO, Mario - GERMANY  
Dr. AREAN, Daniel - GERMANY  
Mr. BAGROV, Andrey - NETHERLANDS  
Mr. BEA BESADA, Yago - SPAIN  
Dr. BRATTAN, Daniel - ISRAEL  
Dr. CASTRO, Alejandra - NETHERLANDS  
Mr. CONDE PENA, Eduardo - BELGIUM  
Mr. CONTI, Gabriele - BELGIUM  
Prof. COSTA, Miguel - PORTUGAL  
Prof. CRAPS, Ben - BELGIUM  
Dr. DETOURNAY, Stephane - BELGIUM  
Dr. DJURIC, Marko - PORTUGAL  
Dr. DOMOKOS, Sophia - UNITED STATES OF AMERICA  
Dr. DONOS, Aristomenis - UNITED KINGDOM  
Dr. ELANDER, Daniel - UNITED STATES OF AMERICA  
Dr. ERDMENGER, Johanna - GERMANY  
Prof. EVANS, Nick - UNITED KINGDOM  
Dr. FAEDO, Antón - SPAIN  
Dr. FERNANDEZ, Daniel - GREECE  
Mr. FONDA, Piermarco - ITALY  
Dr. GARY, Michael - AUSTRIA  
Prof. GAUNTLETT, Jerome - UNITED KINGDOM  
Dr. GIANGRECO PULETTI, Valentina - ICELAND  
Prof. GIOMBI, Simone - USA  
Dr. GOUTÉRAUX, Blaise - SWEDEN  
Prof. GRAN, Ulf - SWEDEN  
Prof. GREEN, Andrew - UNITED KINGDOM  
Prof. GRIGNANI, Gianluca - ITALY  
Dr. GUDNASON, Sven Bjarke - SWEDEN  
Dr. HARMARK, Troels - DENMARK  
Dr. HARTONG, Jelle - DENMARK  
Dr. HOSSENFELDER, Sabine - SWEDEN  
Dr. HOYOS BADAJOZ, Carlos - ISRAEL  
Dr. IHL, Matthias - PORTUGAL  
Ms. IRAKLEIDOU, Maria - AUSTRIA  
Dr. ISHII, Takaaki - GREECE  
Dr. JARVINEN, Matti - GREECE  
Dr. KERÄNEN, Ville - UNITED KINGDOM

Dr. KIM, Keun-Young - REPUBLIC OF KOREA  
Prof. KIM, Nakwoo - REPUBLIC OF KOREA  
Prof. KIRITSIS, Elias - GREECE  
Dr. KRIKUN, Alexander - SWEDEN  
Dr. LIPPERT, Matthew - NETHERLANDS  
Prof. MAGNOLI, Nicodemo - ITALY  
Dr. MARINI, Andrea - ITALY  
Dr. MARMIROLI, Daniele - SWEDEN  
Dr. MEZZALIRA, Andrea - BELGIUM  
Dr. MUSSO, Daniele - ITALY  
Mr. NEWRZELLA, Max-Niklas - GERMANY  
Prof. OBERS, Niels - DENMARK  
Dr. PACHOL, Anna - ICELAND  
Dr. PEÓA-BENITEZ, Francisco - GREECE  
Dr. POLICASTRO, Giuseppe - FRANCE  
Dr. PONOMAREV, Dmitry - GERMANY  
Dr. POURHASAN, Razieh - ICELAND  
Prof. RAMALLO, Alfonso - SPAIN  
Dr. REBHAN, Anton - AUSTRIA  
Mr. REN, Jie - GREECE  
Dr. ROSEN, Christopher - GREECE  
Prof. ROSS, Simon - UNITED KINGDOM  
Prof. ROZALI, Moshe - CANADA  
Prof. SCHALM, Koenraad - NETHERLANDS  
Dr. TARRIO, Javier - SPAIN  
Prof. THORLACIUS, Larus - ICELAND  
Prof. TONG, David - UNITED KINGDOM  
Dr. TONNI, Erik - ITALY  
Dr. VAN REES, Balt - SWITZERLAND  
Prof. VANDOREN, Stefan - NETHERLANDS  
Dr. VANEL, Thomas - FRANCE  
Dr. VOLIN, Dmytro - IRELAND  
Dr. WITHERS, Benjamin - UNITED KINGDOM  
Prof. ZAAANEN, Jan - NETHERLANDS  
Dr. ZINGG, Tobias - NETHERLANDS

The complete list of participants with affiliations can be found at  
<http://agenda.albanova.se/internalPage.py?pageId=256&confId=4191>