



Science Meeting – Scientific Report

The scientific report (WORD or PDF file - maximum of seven A4 pages) should be submitted online within two months of the event. It will be published on the ESF website.

Proposal Title: Holography and strongly coupled plasmas in the Veneziano limit

Application Reference N°: Science Meeting 5579

1) Summary (up to one page)

The workshop entitled “Holography and strongly coupled plasmas in the Veneziano limit” was held in the University of Barcelona between November 10th and 14th, 2014. This workshop was co-funded by the ESF via the Holograv program and by the ERC starting grant HoloLHC-306605.

A total of 18 participants, including convenors, took part in the 11 talks and several discussions that arose during the length of the workshop. The participants of course had different points of view on how to address the current problems of the field, which translated in inspirational discussions, sometimes reaching a consensus and sometimes leaving open questions.

Three of the talks given were based on papers published in the month before the workshop took place, and two more on work in progress that was not public at the time of its presentation to the audience. This shows that the topic of the workshop is still an active line of research in the AdS/CFT community.

The schedule of the workshop was planned to foster discussion. The period between talks was at least 105 minutes to make sure that the speakers had enough time to clarify the questions from the participants. Furthermore, slightly talk-unrelated topics were also debated whenever they arose, prioritizing the exchange of ideas over the schedule.

In summary this week-long workshop helped to reach an understanding of the last results in the problem of studying strongly coupled theories in the Veneziano density via the holographic correspondence, and also to put in common what

different participants believe are the most accessible and interesting problems to address next.

2) Description of the scientific content of and discussions at the event (up to four pages)

The scientific scope of the workshop was to present the current status and future prospects for research in strongly coupled field theories with holographic duals, in models with comparable amounts of degrees of freedom transforming in the adjoint and fundamental representations of the gauge group (Veneziano limit).

This line of research has the long-term scope of better understanding the strongly coupled sector of quantum chromodynamics (QCD, the gauge theory describing the strong interaction between quarks) by studying classes of theories that present similar characteristics, in particular the understanding of the phase diagram of the theory at finite temperature and charge density.

The first talk of the workshop (see the schedule below for speakers and titles) conveyed QCD in the Veneziano limit to help settle what are the physical effects that a holographic approach would be able to address, since such a line of action requires the consideration of certain approximations which might dilute or enhance some of these effects. The same day a summary was given on how to build up a model that reproduces, by construction, some of the known phenomenology of non-perturbative QCD, and makes new predictions on the strongly coupled sector of the theory. These models may also help identifying what are the physical mechanisms that take place in the field theory. A different talk along the same line of reasoning was presented on Wednesday morning, where the problem of modelling the spectra of asymptotically free gauge theories from holography was discussed.

A complementary course of action to use holography to study strongly coupled field theories is to consider models obtained from a mathematically consistent construction: string theory. These type of models were presented in 4 out of 11 talks (two on Tuesday afternoon, first talk on Wednesday afternoon and Thursday morning). From the modelling point of view these setups are on a more solid ground since the holographic duality works at its best. However they are technically more challenging, and additional approximations are needed. In these talks the extra requirements in the field theory were exposed and their consequences discussed, as well as what are the effects on physical observables, and whether they are justified in the long-term project of understanding the phase diagram of QCD.

There were three different talks to describe holographic models of Yang-Mills theories with flavor in the Veneziano limit, reflecting the manifold of options one has to model such a class of system. The last talk on Tuesday treated $N=4$ SYM with flavor degrees of freedom, which is the best studied theory with a holographic dual. Despite its rich structure the theory lacks some of the most important properties of QCD, for example confinement. A different model that incorporates confinement is Witten's model, whose extension to include flavor in the Veneziano limit was discussed on Thursday morning. Accompanying the talk on $N=4$ SYM on Tuesday afternoon there was a discussion on how the lower-

dimensional counterpart of this theory (with two spatial directions instead of three) behaves, since special properties make the model more tractable, and generalizations to include charge density are simpler to carry, perhaps shedding light on the behaviour of the higher-dimensional theory.

The two talks on Wednesday afternoon were devoted to the study of gauge theories at finite charge density. First by discussing from a field theory perspective what are the implications of the finite charge, and second by considering the holographic models of strongly-coupled Yang-Mills theories in the presence of an external charge density. The finite densities are also needed to study the consequences of gauge anomalies, and a talk on Thursday afternoon was devoted to describe this topic and why considering the Veneziano limit is important to capture deviations from results that are otherwise protected by non-renormalization theorems.

The Veneziano limit of field theories is also of interest for theories beyond QCD. For example, on Tuesday morning we had a talk and discussion about the holographic dual of the Kondo model, which shares some technical aspects with the models devoted to the study of QCD. On Friday there was a talk on the inclusion of matter in the fundamental in the ABJM model, which is a 2+1 dimensional Chern-Simmons theory under great control in the holographic side and that is interesting for condensed matter applications.

3) Assessment of the results and impact of the event on the future directions of the field (up to two pages)

The main objective of the workshop was to get together some of the leading scientists that have been working in the last years in the problem of strongly coupled field theories in the Veneziano limit, the interchange of recent results and new points of view, and discuss what are the main goals and hopes for the future of the field.

During the discussions originated in the different talks several conflictive points arose on how to interpret different results. Several times two different points of view were presented and a consensus was reached in many instances, clarifying some misconceptions and missing points. Inevitably, in some other cases this consensus did not exist, as is normal (and perhaps desirable) in ongoing research.

In other instances the discussion topic was how to identify the smoking gun of a particular physical effect. One example is how to identify the spontaneous symmetry breaking of a gauge symmetry in a gauge invariant way, since the field theory language allows for a gauge-dependent statement most of the community is used to and talks about in a natural fashion, but in the holographic context this is not possible. Understanding this point is of key importance to develop one of the future directions of the field: the characterization of a color superconducting phases in the phase diagram of QCD. This type of discussions, concerned with the advance of the field and how to identify interesting phenomena, are enough to make worth this type of workshops.

Some other discussions revolved around the modelling of a non-abelian flavor group, where only a limited number results are known, and technical problems arise. Unfortunately, this is an example of a long-standing problem in the field, and a week workshop is not enough to bring a solution to it.

One of the most important conclusions of the workshop, if not the most important, was the interchange in ideas of what to study next. It was clear from the talks and discussions that there are several possibilities on what lines of research are worth pursuing. Some participants favoured the ones related to the modelling of physical observables, whereas others preferred to investigate the mechanisms leading to different types of phenomenology in a qualitative way. This guarantees that in the near future the study of strongly coupled field theories in the Veneziano limit will still be an active line of research, with a numerous number of accessible and interesting problems to address.

4) **Annexes 4a) and 4b): Programme of the meeting and full list of speakers and participants**

Annex 4a: Programme of the meeting

Monday 10th

11:00 - Arrival

14:00 **Elias Kiritsis** – *QCD in the Veneziano Limit*

15:45 **Francesco Nitti and Matti Järvinen** – *Phenomenological holographic models for large- N QCD*

Tuesday 11th

11:00 **Johanna Erdmenger** – *Backreaction in a holographic model of the Kondo effect*

14:00 **Anton Faedo** – *Smeared flavours in holography and three-dimensional gauge theories*

15:45 **Francesco Bigazzi** – *D3-D7 Quark-Gluon plasma*

Wednesday 12th

11:00 **Nick Evans** – *Dynamic AdS/QCD & the Spectra of Asymptotically Free Gauge Theory*

14:00 **Prem Kumar** – *Cold dense heavy-quark matter and holography*

15:45 **Arnab Kundu** – *Large N Yang-Mills Theories at Finite Density*

Thursday 13th

11:00 **Aldo Cotrone** – *Holographic QCD with Dynamical Flavors*

15:45 **Umut Gursoy** – *(Non)-renormalization of anomalous conductivities and holography*

Friday 14th

11:00 **Alfonso Ramallo** – *Flavors and fluxes in the ABJ(M) model*

14:00 - Departure

Annex 4b: Full list of speakers and participants

Speakers

- Francesco Bigazzi
- Aldo Cotrone
- Johanna Erdmenger
- Nick Evans
- Anton Faedo
- Umut Gursoy
- Matti Järvinen
- Elias Kiritsis
- Prem Kumar
- Arnab Kundu
- Francesco Nitti
- Alfonso Ramallo

Other participants

- Javier Mas
- David Mateos
- Andrew O'Bannon
- Christiana Pantelidou
- Angel Paredes
- Javier Tarrío