Projet de recherche doctorale - Initiative Physique des Infinis

Defects and interfaces in conformal field theory and cosmology

Giuseppe Policastro (LPENS, Paris)

Shira Chapman (BGU, Beer Sheva)

The PhD research project we propose focuses on the study of transport properties of defects and interfaces in the framework of the holographic gauge/gravity correspondence. This topic is of great interest in many contexts, from high-energy theory to condensed matter theory and cosmology.

In high-energy theory, defects can be used as probes into dynamical aspects of a quantum field theory (symmetry breaking, higher-form symmetries, dualities etc.), moreover it has been recognized recently that they play a structural role, in the sense that the complete definition of a theory cannot be obtained by considering only the algebra of local operators but requires introducing non-local objects.

In condensed matter, of course, defects and boundaries appear in almost any real-world system and their effects must be taken into account in order to have successful phenomenological models. There are many important effects whose presence crucially requires the presence of boundaries or impurities (Quantum Hall conductivity, edge modes of topological materials etc.).

In cosmology, it is natural to expect that defects will be formed when the universe undergoes a symmetry breaking phase transition, and they may have played a role in seeding the formation of cosmological structures. However our proposal follows a different route where defects are used as a tool to make cosmological predictions, as we explain below.

In our previous collaboration, we have used the holographic correspondence to study the properties of interfaces between conformal field theories in 2 dimensions. In the simplest holographic model, these are dual to branes separating patches of AdS_3 geometries. In this setup we could obtain analytic results for the holographic quantum complexity of the defect [1] and for the energy transmission and reflection coefficients [2]. The latter are important data that characterize the interface CFT, and our work provided their first holographic computation. In [3] we showed that an extension of our method allowed the computation of the transport coefficients for a different class of models where the defect is dual to a smooth geometry. The basic idea is that the smooth geometry can emerge as the limit of a densely distributed stack of branes.

Our work opens up many directions for future investigations that this PhD project will contribute to explore. Some of the possible lines of research are the following:

1) Investigate the universality of the energy transport coefficients in the holographic models (they are known to be universal in 2d CFT, in the sense of being independent of the excitations that carry the energy). In our previous work we could only compute it assuming the universality.
2) Study a larger class of holographic models, including higher-derivative corrections, additional matter on the brane, and especially considering the case of general spacetime dimension.

3) Study the properties of higher-point functions of the energy-momentum tensor in presence of an interface; they would encode non-linear generalization of the transport coefficients which are at present largely unexplored.
4) Study the algebra generated by the fusion of defects; the fusion operation is expected to be singular in field theory, but the simplest holographic model does not show such divergencies. We plan to address this discrepancy by studying the holographic partition function in presence of defect branes.
5) Study possible generalizations and applications of our method of approximating smooth geometries by distribution of branes. In particular, one tantalizing application would be to use an analytic continuation of the AdS_3 solution to obtain de Sitter solutions. Modeling cosmological evolution as a sequence of space-like branes (one can also think of them as instantaneous quenches) could prove to be fruitful as a computational method to extract cosmological observables.
6) In addition to the previous point, the cosmological evolution can also be combined with the holographic duality using the so-called “centaur geometries” in 2d and possible generalizations in higher dimensions. These are asymptotically AdS spaces which contain pockets of dS [4], thereby allowing the use of the holographic correspondence to address questions of cosmology.

It is to be noted that the two proponents already have some experience in effectively codirecting doctoral research projects, as our publications [1,2,3] were joint works with our respective PhD students, namely Dongsheng Ge (GP) and Tal Schwartzman (SC). Moreover, the two proponents hold a collaboration grant by the Israel Science foundation which will provide a budget for long term stay in Ben-Gurion University for the student.

The student will benefit from exposure to different research groups and different environments. In ENS he can get expertise in formal aspects of defect CFT and QFT in general. In Ben Gurion university he will be able to interact with experts in cosmology and different aspects of holography. In both places he will interact with a large community of postdocs and students. By leveraging the unique strengths of both institutions, this collaboration will foster an environment of interdisciplinary learning and scientific growth for all involved.

The profile we look for is a student with a formal background, having a very good knowledge of QFT and beyond, and possibly capable of doing some coding and light numerical work.

Relevant publications:

1) S. Chapman, D. Ge, G. Policastro, “*Holographic Complexity for Defects Distinguishes Action from Volume*”, JHEP 05 (2019) 049, arXiv:1811.12549 [hep-th]
2) C. Bachas, S. Chapman, D. Ge, G. Policastro, “*Energy Reflection and Transmission at 2D Holographic Interfaces*”, Phys.Rev.Lett. 125 (2020) 23, 231602, arXiv:2006.11333 [hep-th]
3) C. Bachas, S. Baiguera, S. Chapman, G. Policastro, T. Schwartzman, “*Energy transport for thick holographic branes*”, arXiv:2212.14058 [hep-th]
4) S. Chapman, D.A. Galante, E.D. Kramer, “*Holographic complexity and de Sitter space*”, JHEP 02 (2022) 198, arXiv:2110.05522 [hep-th]

Projet soumis avec l’accord de la direction du laboratoire