Research Statement

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1 Research experience

My research experience in string theory encompasses two-dimensional conformal field theory and its applications to various areas in high energy physics. As a rich avenue with open questions and insight for techniques applicable to other areas of string theory, conformal field theory (CFT) in 2D provides us with a good handle on different research topics. Formerly, my research experience entailed work on CFT correlators with relation to holography. More recently, my work has been on topological defects on the worldsheet.

My project on CFT correlators focused on finite-temperature three-point functions for primary fields in momentum space. Such objects are a necessary ingredient in the study of the posited Kerr/CFT duality via the comparison with absorption cross sections. The various approaches to generalize AdS/CFT, such as AdS/CMT [1] and Kerr/CFT [2, 3], have given importance to the computation of finite-temperature correlation functions. The reason is that many of these holographic dualities contain black holes and thus describe dual field theories at finite temperature. In order to compare the scattering amplitudes of a system like Kerr black hole one works in momentum space. For example, in [4, 5] it was shown that the reaction of near-horizon region of an extreme Kerr black hole to an incoming wave of a free scalar can be reproduced by a two-point function of a finite-temperature CFT. This work was furthered by [6] where it was shown that similar results hold for spinors two-point functions.

A strong test of any such holographic duality with a black hole would be to reproduce a general three-point function from the CFT using the bulk data. With this in mind, the work I was part of in [7] obtained the general expression of the three-point function in momentum space. This is a promising direction for Kerr/CFT since extremal three-point functions have been obtained using holographic techniques in [8]. An extremal three-point function in 2D CFTs is a special case where the correlation function becomes the product of a pair of two-point functions. Our result for the general three-point function at finite-temperature in momentum space reduces to the correct expression of a product of two two-point functions in these coordinates. Furthermore, our result has a similar frequency dependence as the greybody factors found in black hole absorption cross-sections in [9].

More recently, my work has been in the area of topological defects [10, 11, 12]. A defect is a one-dimensional object in two-dimensional theories, and more generally a submanifold of positive codimension in higher dimensional spaces. Defects in 2D carry two distinctive characteristics. One is that defects come with a binary operation called “fusion”. Under fusion two defects $D_1$ and $D_2$ can be smoothly brought together to form a new defect, say $D_3$. We denote this operation by $D_1 \ast D_2 = D_3$. Secondly, defects encode information about symmetries, dualities, and mappings between the theories at either side of the defect. An important class of defects are those called topological defects which commute with the energy-momentum tensor. In this case, the defect can be deformed through the worldsheet without affecting the values of the correlation functions.

My work on defects has been the construction of topological defects between non-compact orbifolds $\mathbb{C}/\mathbb{Z}_n$ which form a representation of the renormalization group flow between these theories [13]. It turns out that superstring theory on $\mathbb{C}/\mathbb{Z}_n$ can be naturally expressed as an orbifolded Landau-Ginzburg (LG) model; either by directly introducing superspace formalism or via mirror symmetry. Under this characterization, we used the algebraic language of matrix factorization to describe the defects. Given a ring $R$, a matrix factorization of a polynomial $W$ is given by two $R$-modules $P_0$ and $P_1$, and two maps $p_1 : P_1 \to P_0$ and $p_0 : P_0 \to P_1$ such that $p_0 p_{i+1} = W 1_i$, where $1_i$ is the identity on $P_i$. The theory of defects as matrix factorizations of the superpotential of LG models was developed in [10]. They showed that to a defect $D$ between two LG models with superpotentials $W_1$ and $W_2$, one associates a matrix factorization of the polynomial $W = W_1 - W_2$. Fusion of defects in this formalism corresponds to the tensor of matrix factorizations.

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In [13] we extended the work of [14] which describes the boundary RG flow in Landau-Ginzburg models and supersymmetric minimal models in terms of topological defects. Our work generalizes the results of [14] to the non-supersymmetric case of the non-compact $\mathbb{C}/\mathbb{Z}_n$ theories. The orbifold $\mathbb{C}/\mathbb{Z}_n$ is physically relevant because it is the simplest model to study tachyon condensation [15]; the tachyons are closed strings localized at the fixed points of the orbifold group action. We showed the existence of suitable defects which sit at the interface between the IR and UV theories.

Aside from showing the existence RG flow defects between the $\mathbb{C}/\mathbb{Z}_n$ orbifolds, in [13] we showed that we can use these defects to tackle the question of the boundary RG flow when the theory has a nontrivial worldsheet boundary. The behavior of boundary degrees of freedom under renormalization group (RG) flow represents a problem in both string theory and condensed matter physics that is not fully understood [16], [17]. We provided evidence that the defects successfully map the boundary conditions associated with the IR theory $\mathbb{C}/\mathbb{Z}_n$, to those of the UV theory $\mathbb{C}/\mathbb{Z}_n'$, $n' < n$.

2 Present interests and future directions

My current research interests are defects in two and higher dimensions; specifically providing new examples and using characteristics intrinsic to defects to obtain new approaches to problems in field theory. The theory of topological defects is versatile and powerful enough that many important aspects of string theory can be written in terms of these extended objects. For example, symmetries and order-disorder dualities were discussed in [18]; examples of T-duality defects were constructed in [12]; and RG flow defects have been proposed for different 2D theories in [14] [11] [19]. Although progress has been made describing defects and applying them, it is important to note that only for the compact boson the spectrum of possible defects has been cataloged [18] [20].

Presently I am involved in a project mapping out the spectrum of defects between the bosonic theories with target space $S^1_R/\mathbb{Z}_2$ where $R$ is the radius of the circle. This work aims to reduce the dearth of theories for which defects are known. With this current project and the work of [20], the moduli space for the $c = 1$ 2D CFTs will have its spectrum of defects known. This orbifolded theory does not admit a LG description. The defects are obtained instead via the unfolding procedure of [20] which is the inverse of the “folding trick” found in the CFT literature. The folding trick gives a correspondence between two theories $\text{CFT}_1$ and $\text{CFT}_2$ separated by a defect, and the theory $\text{CFT}_1 \otimes \text{CFT}_2$ with a boundary corresponding to the defect.

My future research directions includes the study of boundary degrees of freedom in boundary theories, as well as the use of properties of defects to learn about the behavior of bulk theories. The characterization of boundary degrees of freedom by fusing defects which carry the action of some symmetry has been a successful program so far [14] [21] [13]. The other research direction that builds on my past and current work with defects is the study of the Casimir force between defects [19] [22]. This is a new characteristic for CFTs which can only be considered with the introduction of defects. This is an important tool because the repulsion or attraction between defects, or a defect and a boundary, can be related to information about the bulk theories between the defects. For example, in [19] the Casimir force was used to extract information about the RG flow between the compact boson theories. I plan to extend this work to the orbifolds $S^1_R/\mathbb{Z}_2$ and $\mathbb{C}/\mathbb{Z}_n$. There we can also study the twisted sectors, and in the latter provides a natural relation between tachyon condensation and the Casimir force between defects.

Lastly, I am interested on the connection between topological defects in 2D CFTs and holography. This is an open area which could give more insight into holographic duals. The first step would mean finding what the corresponding bulk representation of the boundary CFT defects is.

References


