String Duality Primer

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1 Introduction

A series of lectures on the string duality are given for the beginner by the beginner at Niigata-Yamagata joint workshop held on Oct. 31 - Nov. 1 (1997). The purpose of the lectures is to lower the hurdle which most of the students feel, saying "how can we understand the string duality?" We have to know at least, what is going on in the field of strings, even if we are working on the other fields. Therefore, the lectures are tried to clarify the physical meaning of the theories as intuitively as possible, without pursuing rigidty.

2 Superstrings and D-branes

2.1 Neveu-Schwarz-Ramond Model

Following the paper by M. Ito, T. Morozumi, S. Nojiri, and S. Uehara [1], BRS quantization of the superstring is presented, staring from the BRS quantization of the gauge theories, where a little modification is added on the boundary conditions, Neumann v.s. Dirichlet, in order to cope with the recent development on the D-branes.

2.2 D-branes and Ramond-Ramond Charges

Reproduction of the paper by Polchinski [2] is tried by explaining the full details of the calculation. The way of estimating the one loop string diagramas as well as the derivation of the modular (Jacobi's iamginary) transformation are given in order to see explicitly the Ramond-Ramond coupling to the D-brane.

3 Dynamics of D-branes

3.1 Effective Dirac-Born-Infeld Action

A rule of thumb "derivation" of the Born-Infeld action for D-branes [3]-[9] is tried [10], based on the Fradkin and Tseytlin's approach. The method is only to integrate out the unnecessary bosonic and ferimionic string coordinates from the action which couples with the external background fields.

3.2 Examples of Dualities in Type IIB and Type IIA Superstrings

Base on the papers [11], [12], and [8] string dualities are discussed using the low energy effective actions as well as the D-branes' effective actions. Type IIB superstring may be self-dual under the exchange of the strong and the weak coupling regimes, whereas the strong coupling regime of Type IIA superstring may be the 11D supergravity.

4 M Theory and Matrix Model

4.1 M theory in the infinite momentum frame v.s. $U(\infty)$ SUSY Quantum Mechnics

Following the papers by T. Banks, W. Fischler, S. H. Shenker, and L. Susskind[14] and by E. Witten [15], M theory in the infinite momentum frame and $U(\infty)$ SUSY quantum mechanics are discussed. Essence of the connection between two theories is very simple, that is, two parmeters of the membrane and string variables can be considered as if the infinite componet row and column indices of the matrix. Therefore, membrane and string are reduced to the matrix quantum mechanics and the reduced matrix model on a single space-time point. For the latter reduced matrix model, the recently proposed [16] constructive definition of the Type IIB superstring is also briefly discussed, where the $U(1)^D$ symmetry breaking [17] may become important once more for the compactification to occur.

4.2 11D Supermembranes

Starting from the bosonic p-branes [18], 11D supermembranes are constructed [19] and its light cone quantization is performed [20], where the importance of the Wess-Zumino term and the κ symmetry is stressed.

5 Non-Commutative Geometry

For the future purpose, mathematics of the non-commutative geometry of Alain Conne and its application to the standard model are reviewed, based on the papers [21]. Here, what we are not familiar with is tried to understand: 1) Dirac operator gives the metric of the space, 2) the fermionic mass term is the Dirac action and 3) the Higgs potential is the Yang-MIlls action.

6 Conclusion

After these series of lectures, we will probably be able to follow the newly appearing papers on the string duality and to develop new insights in this field and the others. The important point is, however, to deveolp the interesting connection of the superstring theories in the strong coupling regime with the presently accessible world of TeV scale. The problem which always stands in our way is the huge gap between string scale 10^{19} GeV and ours TeV. This time we hope to overcome the difficulty.

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