D-branes in Big Bang/Big Crunch Universes

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The investigation of string theory on cosmological backgrounds is important because stringy effects should be relevant to resolve the singularity in early universe. In general, it is a difficult task because there are only few solvable models for strings on these cosmological universes. Recently, simple models were proposed by Liu, Moore and Seiberg [1, 2], where orbifold technique was used. Among similar models studied since then, we consider a simpler universe, so-called Misner space. Strings on the space were studied, for example, in [3]. Misner space can be constructed as two dimensional Minkowski space-time with the identification of a discrete boost. The result space includes four regions; two of them include big crunch/big bang singularity and the other two include closed time-like curves. The closed strings in twisted sectors are supposed to resolve the big bang singularity [3], but a clear conclusion has not been made yet.

In our work [4], we have investigated how D-branes feel these pathologies. In this space, there are D0-brane with a spiral orbit and D1-brane wrapping the whole space. We have computed annulus amplitudes for open strings on the D0-brane and the D1-brane and found imaginary parts of the amplitudes. The D0-brane may be expressed as the infinite sum of image branes under the discrete boost in the covering space. Then, the imaginary part can be understood as the absorption ratio between image branes, and also identified as the pair creation rate of open strings between image branes. We should remark that the pair creation occurs near the big bang singularity, where the image branes approach each other. For D1-brane, the imaginary part is interpreted as the emission rate of the twisted closed strings, which is due to the time-dependence of the background. Since the imaginary part diverges, the back-reaction of the emission should be very large. We have also investigate $2 \to 2$ scattering amplitude for open strings. The 4 point function for closed strings was computed in [5], and it was found that the amplitude diverges due to graviton exchange near the big bang singularity, which is a signal of large back-reaction. We have shown that the $2 \to 2$ scattering of open strings is less singular because gauge field is exchanged instead of graviton.

References

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