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The Off-shell Sphere Partition Function

In standard textbooks of string theory, we learn that due to conformal invariance, the 0, 1 and 2-point functions of bulk vertex operators on genus-0 Riemann surface all vanish. This is another way of saying string theory is only defined on-shell. However, it is sometimes important to have a sensible formulation of string theory in off-shell target space backgrounds (those with non-vanishing beta functions of background fields). For example, to calculate the Bekenstein-Hawking entropy in a conical background using the Gibbons-Hawking method, Susskind and Uglum used Tseytlin's nonlinear sigma model-based prescription for constructing off-shell classical effective actions. Tseytlin's off-shell prescription relates the path integral of a renormalizable non-linear sigma model on the worldsheet sphere Z_{S^2}, to an off-shell target spacetime effective action I_{eff}, for the masless string modes using renormalization group techniques. Precisely, it says that $I_{\text{eff}} = \frac{d}{d \ln \epsilon} \ln Z_{S^2}$ where ϵ is the short distance UV cutoff.

Unfortunately, despite being around for more than three decades, several aspects of Tseytlin's off-shell prescription remain unclear. In this talk, I will clarify several aspects of this prescription. Using renormalization group arguments, I will justify and demonstrate the validity of Tseytlin's prescription and particularly emphasize how the logarithmic divergence in the volume of the $\text{SL}(2, \mathbb{C})$ Mobius group (of the worldsheet sphere) is used to control the transition from an on-shell to off-shell action. I will explain how the Euclidean S-matrix relates to its Lorentzian counterpart using the Schwinger propagator method. I will also show how Tseytlin's off-shell prescription, by not fixing the Mobius gauge (the three points on the sphere), introduces an explicit BRST anomaly in the boundary of the moduli space of $\text{g} = 0$ Riemann surfaces. Finally, the talk will explore more recent work of how Tseytlin's prescription can be used to calculate the entropy of additional curved spacetimes, such as the $\text{SL}(2, \mathbb{R})/\text{U}(1)$ cigar geometry.

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