Research Statement

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I am a master student at University of Amsterdam with interests in string cosmology, low-energy effective theory of superstring, and string mathematics regarding compactification. The stability of de Sitter vacua constructed by KKLT uplifting/KPV has been argued for long time. Some researchers stated that the unphysical singularities always exist once the backreaction has been considered. However, several studies investigated that the adaption of temperature for anti-D3 branes can rescue this long-lasted problem from the fatal singularity, which is also the foundation of my master thesis and following work.

The majority of my current research is composed by the comparison of (1) and the second result of (2). One surprising fact is that the geometry (with internal S^2) around the meta-stable vacua of (1) can be transit to that of KS black hole horizon (without internal S^2) of (2). This transition is controlled by a charge related to the D3 current. Once the sign of charge undergoes a transition from negative to positive, the $S^2 \times S^3$ structure at meta-stable state with S^2 wrapped will degenerate its internal structure and decouple the wrapping of S^2, finally, one obtains a KS black hole horizon without internal S^2 and with positive D3 charge, namely, the instability will appear at this stage. We conclude that the KS black hole of (2) is an unstable case contained in Fig. 1 of (1) for large p (entropy). My potential next step is to generalize the perturbation to non-extremal case and examine if instability range still exists.

This research statement is organized as follows: The first section discusses my master thesis in details, with a focus on the methodology. The second section discusses my future potential research on de Sitter uplifting.

Non-extremal De Sitter Stability

Current Work:

As I stated above, my current work is mainly focusing on the stabilities of de Sitter spacetime. Similar to what (1) did, I also analyzed the blackfold equations, which is based on stress-tensor conservation and charge conservation equations, in the pattern of $\overline{D3}$-$NS5$ polarization bound state. Beside the equations which can recover the usual KPV equations of motion derived by DBI action, I further considered the first order perturbation for blackfold equations, from which one obtains an instability on radial coordinate controlled by a parameter describing dissolved D3 charges. A comprehensive computation can be found in a recent paper (4). That parameter displays a transition from negative charge (stable) to positive charge (unstable), in which the unstable range is pretty small because of its perturbative nature.

Contrary to the meta-stability (1) obtained, the second result of (2) shows a KS black hole solution which always hold positive charge and thus the instabilities cannot be cloaked by the horizon. Although the original work is based on the KS gauge theory, it is not hard to apply blackfold formalism for it and compute the corresponding D3, NS5 charges and KPV meta-stability equations. After then, one can show that the p value, which corresponds to the number of $\overline{D3}$, could be located at the range in which the effective potential has unstable vacuum. This reveals that the KS black hole discussed in (2) is just one possible pattern covered by (1)'s results. Besides, the charge transition implies that the geometry with internal S^2 can be moved into the geometry without such structure and holds instability, which is consistent to the non-extremal configuration (1) discussed. The last few steps are still on going.

Future Work: A related question I am going to work on is based on the non-extremal perturbation and the corresponding instability range. As (4) suggests, the perturbation equations in extremal limit imply that the stability hold for a large range of p value, besides, a small range of instability also exists. This has been an updated version of (3)'s argument that localized $\overline{D3}$ always has instabilities. By applying similar perturbation for the non-extremal blackfold equations given by (1), one can further investigate if such small unstable range still exist or not. Either case will provide us more information about antibranes polarization in non-extremal case. If such range exists, the similar behavior for both extremal and non-extremal cases tell us the conclusion of (3) has to be refined. The singularity can be cloaked by the horizon for a large range of p (at least to 0.08 magnitude). If such range is vanished, that would be a much more surprising fact, which means the horizon can totally cloak the antibrane singularity, and KKLT/KPV meta-stable states with de Sitter vacua are certainly stable with finite temperature.

Nilpotent Superfields in de Sitter Uplifting

Future Work: Nilpotent superfields have been used as effective descriptions of low energy spontaneous supersymmetry breaking in many papers. In a recent paper (5), the authors proposed a new KKLT-like formalism from IIA superstring/supergravity and analyzed the mass spectrum. Based on (5)'s construction, I am going to add nilpotent superfields into Kahler potential and superpotential, and then calculate the effective mass spectrum and examine the linearity of supersymmetry breaking. It is reasonable that the spontaneous breaking is still non-linearly realized on the goldstino as IIB case, which implies that the appearance of massless goldstino cancels the t' Hooft-like anomaly on $\overline{D6}$. This will strengthen the reliability of (5)'s construction.

Furthermore, one can include the polarization dynamics and determine the transformations near the meta-stability as (6) tried, if IIA uplifting also has its origin of antibrane polarization, we should obtain a similar conclusion that the higher order corrections have to be included in the probe limit since the original KKLT mechanism requires that the supersymmetry breaking scale cannot be decoupled to the uplift energy. This may help us to further improve the IIA uplifting and provide a consistency check from nilpotent superfields' perspective.

References

1. **J. Armas, N. Nguyen, V. Niarchos, N. A. Obers, T. Van Riet.** Meta-stable non-extremal anti-branes. *Phys. Rev. Lett. 122 (no. 18).* 2019, pp. 181601, [hep-th/1812.01067].

2. **I. Bena, A. Buchel, S. Lust.** Throat destabilization (for profit and for fun). 2019, p. 1910.08094.

3. **I. Bena, M. Grana, S. Kuperstein, S. Massai**. Giant tachyons in the landscape. *JHEP 1502*. 2015, pp. 146, [hep-th/1410.0776].

4. **N. Nguyen**. Comments on stability of KPV metastable state. [hep-th/1912.04646].

5. **R. Kallosh, A. Linde**. Mass production of type IIA dS vacua. JHEP 2001. 2020, pp. 169, [hep-th/1910.08217].

6. **L. Aalsma, J. P. van der Schaar, B. Vercnocke**. Constrained superfields on metastable anti-D3-branes. JHEP 1705. 2017, pp. 089, [hep-th/1703.05771].