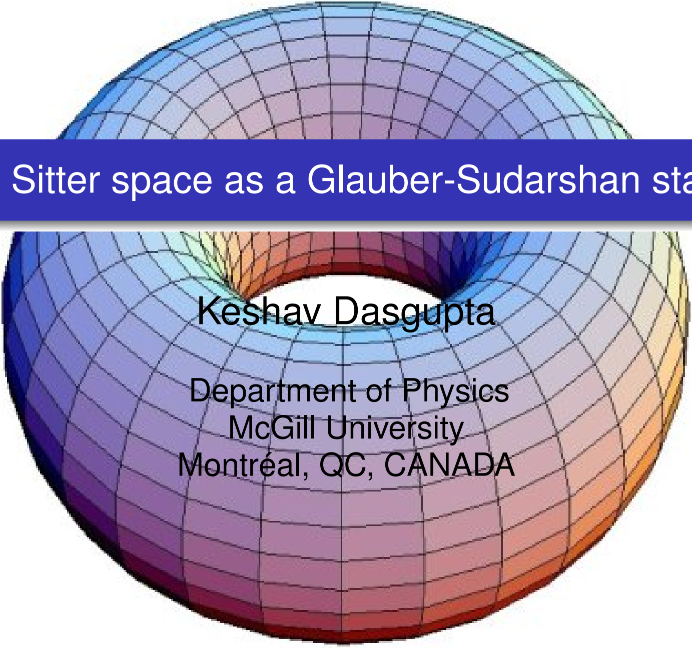
de Sitter space as a Glauber-Sudarshan state



Keshav Dasgupta

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- **Four dimensional de Sitter space is a Glauber-Sudarshan state in string theory I, II, Suddhasattwa Brahma, K.D, Radu Tatar et al 2007.00786, 2108.08365; de Sitter space is a Glauber-Sudarshan state in string theory, 2007.11611**
- **Crisis on infinite earths: short-lived dS vacua in the string theory landscape, Heliudson Bernardo, Suddhasattwa Brahma, KD, Radu Tatar, 2009.04504**
- **Quantum Break-Time of de Sitter, G. Dvali, C. Gomez and S. Zell, 1701.01776; Quantum Breaking Bound on de Sitter and Swampland, G. Dvali, C. Gomez, S. Zell, 1810.11002**

Other relevant papers related to my talk are as follows.

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- **de Sitter vacua in type IIB string theory: Classical solutions and quantum corrections, K.D, Rhiannon Gwyn, Mohammed Mia, Evan McDonough and Radu Tatar 1402.5112.**
- **$\overline{D3}$ and dS, Eric Bergshoeff, K.D, Renata Kallosh, Antoine Van-Proyen, Timm Wrase, 1502.07627**
- **Quantum Corrections and the de Sitter Swampland Conjecture, K.D, Maxim Emelin, Evan McDonough, Radu Tatar, 1808.07498**
- **de Sitter vacua in the string landscape, K.D, Mir Mehedi Faruk, Maxim Emelin, Radu Tatar, 1908.05288; How a four-dimensional de Sitter solution remains outside the swampland, 1911.02604**

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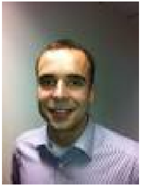

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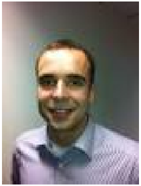

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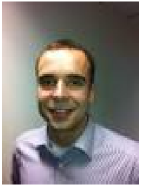

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Summary of the results

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- **How to realize de Sitter in the string landscape**
- **How to realize it as a Glauber-Sudarshan state instead of a vacuum**
- **Why is this a hard problem?**
- **Although hard, it may still be a doable problem!**

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My aim here is to argue that such a system can be solved in string theory!

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which is a de Sitter space with a flat slicing with Λ the cosmological constant and the temporal coordinate t has a range $-\infty \leq t \leq 0$, with the late time regime given by $t \to 0$.

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In the following I'll try to answer at least some of the above questions, while motivating the others.

For computational efficiency we will study this from M-theory point of view, where the metric takes the following form.

$$
\begin{aligned}
ds^2 = \; & g_s^{-8/3}\eta_{\mu\nu}dx^\mu dx^\nu + g_s^{-2/3}\mathrm{H}^2\Big(\mathrm{F}_1(t)g_{\alpha\beta}dy^\alpha dy^\beta \\
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So how are we to realize such a background?

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$$-\frac{1}{\sqrt{\Lambda}} < t < 0$$

Ignoring $\mathrm{H}(y)$ for simplicity. This is interestingly also the bound set up by TCC!

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You could say that it'll then be impossible to solve the system, or some of you may ask: how do we even know that Wilsonian method of integrating out high energy modes work when the modes are themselves changing with respect to time? We will come back to the latter question, if time permits, but for the first question: lets see what we can do.

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So question: what are the allowed perturbative terms at small g_s and low energies?

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i.e. sum over all (l_i, n_i). Note that n_i can be negative, but we take $l_i \in +\mathbb{Z}$. In M-theory the manifold is $\mathcal{M}_4 \times \mathcal{M}_2 \times \frac{\mathbb{T}^2}{\mathbb{Z}_2}$, with $(m, n) \in \mathcal{M}_4$, $(\alpha, \beta) \in \mathcal{M}_2$, $(a, b) \in \frac{\mathbb{T}^2}{\mathbb{Z}_2}$.

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What is the G-flux ansatze? Here it appears three possibilities.

So what is the perturbative energy-momentum tensor?

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What about the quantum terms? Do they have nice g_s expansions?

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n_3 is the number of derivatives along the 11th direction. Note however the presence of the relative minus signs. They occur in two places: in front of n_3 and in front of (l_{36}, l_{37}, l_{38}). The latter are related to the G-flux components of the form $\mathbf{G}_{\rm MN\mathit{ab}}$.

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Sadly we have lost the g_s hierarchy! Which means for any given value of $\theta_E = \theta_F$ there are literally an infinite number of $(\rm stuff, stuff')$, i.e literally an infinite number of perturbative operators contribute.

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This appears to be a clear sign of the loss of g_s hierarchy. Not good, not good at all.

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In our definition of quantum series, we have derivatives along the x_{11} directions (recall the appearance of n_3!). These derivatives kill the M_p suppressions of the quantum terms.

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Sadly no! This is because the troublesome operators that seem to break the g_s hierarchy, are constructed out of localized G-flux components $\mathrm{G}_{\mathrm{MN}ab}$. Because of their localized nature they have hidden M_p's in their definitions, something like $\exp(-M_p^2 x_{11}^2)$, to quote an example.

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In fact we can do even better. We can realize the above background as a Glauber-Sudarshan state over a supersymmetric Minkowski background.

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The EOMs however can only provide a local picture, but the existence of a solution, or even the Glauber-Sudarshan state, relies heavily on global constraints too. The global constraints come from flux quantizations, anomaly cancellations, moduli stabilization etc.

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THANK YOU FOR YOUR ATTENTION!