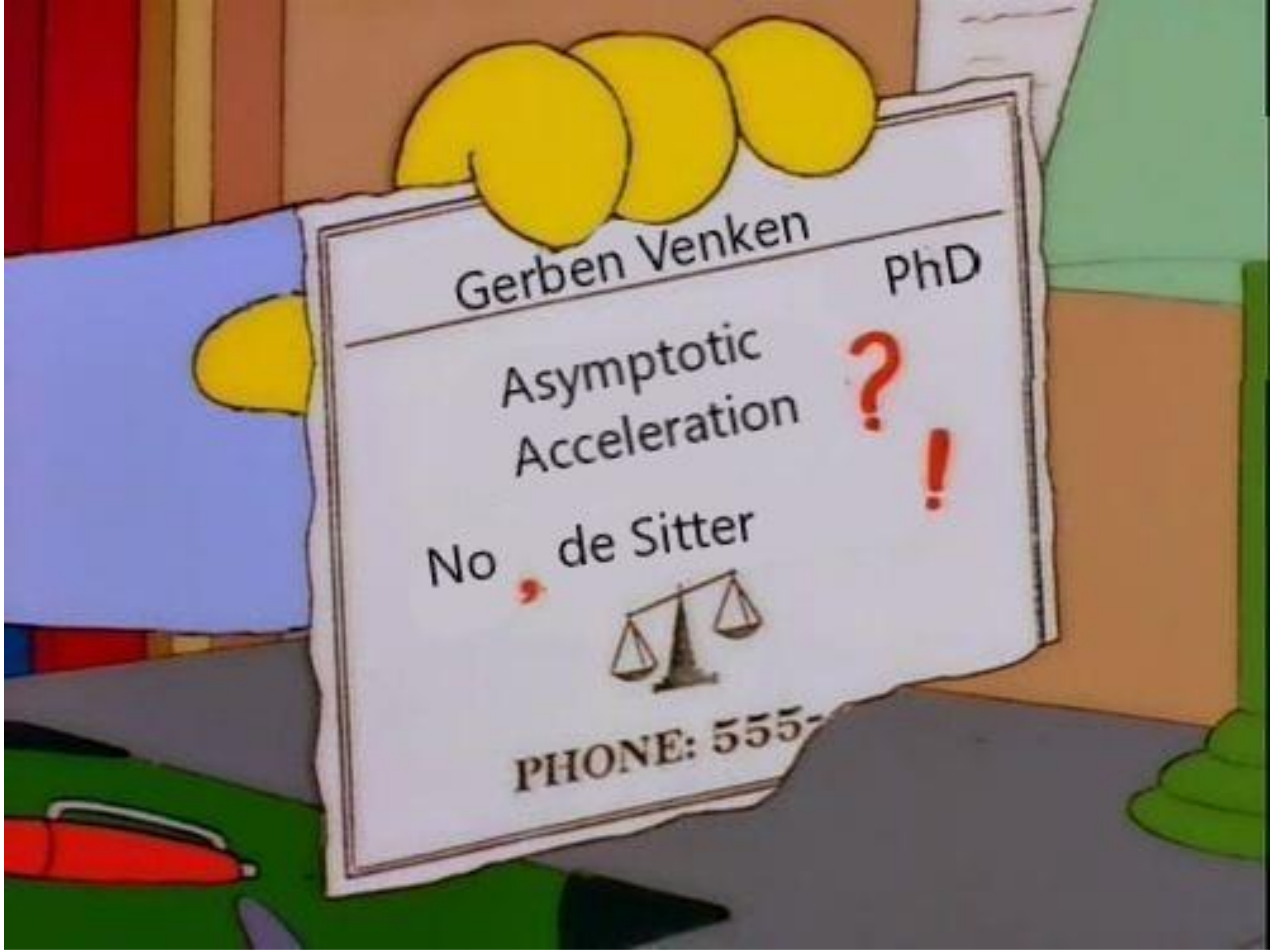
String Phenomenology 06/07/2023

2306.17213 with Arthur Hebecker and Simon Schreyer

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386



String Phenomenology 06/07/2023

2306.17213 with Arthur Hebecker and Simon Schreyer

UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

Motivation

Our world looks like it has accelerated expansion

Still a great struggle to realize this in string theory!

Difficult to get controlled de Sitter [Danielsson, Van Riet ’18; Obied, Ooguri, Spodyneiko, Vafa ‘18; many other papers]

Could be that control in interior moduli space is just difficult

OR something inherently conceptually sick about cosmic horizons

Cosmic horizons <=> accelerated expansion

Much recent attention for accelerated expansion: talks by Hebecker, Andriot, Wrase, Shiu, Scalisi, Tonioni, Nian, Revello + associated papers

[Grimm, Li, Valenzuela ’19; Calder´on-Infante, Ruiz, Valenzuela ’22; van de Heisteeg, Vafa, Wiesner, Wu ‘23; Shiu, Tonioni, Tran ‘23 x2; Freigang, Lust, Nian, Scalisi ’23, Cremonini, Gonzalo, Rajaguru, Tang, Wrase; Apers, Conlon, Mosny, Revello;..]

Parametrically controlled accelerated expansion

Don't need de Sitter for accelerated expansion, can look at rolling scalar

Rolling in interior will have all the control issues of de Sitter

Can we get accelerated expansion in the asymptotics of moduli space

$\Rightarrow$ Arbitrarily controlled accelerated expansion?

If so know there's nothing conceptually wrong with acc. exp.

AA=>dS Conjecture

Conjecture 1 ('Asymptotic Acceleration Implies de Sitter' or 'AA$\Rightarrow$DS'). *Consider a d-dimensional (effective) theory of quantum gravity ($d > 2$). If this theory realizes accelerated expansion through rolling scalars at asymptotically large distance in field space, then this theory is based on the compactification of a $(d + k)$-dimensional theory with positive vacuum energy. Given that no quantum gravity theories exhibit dS vacua in their fundamental dimension, the underlying $(d + k)$-dimensional de Sitter model is itself the result of a compactification.*

There's no escape from de Sitter in the asymptotics!
One must struggle with all the control issues of the interior

Argue for AA=>dS Conjecture

1) Argue that any asymptotic limit of string theory is (dual to) a decompactification limit

2) Argue that our conjecture is true in the decompactification limit

All Asymptotic limits are decompactification limits

Present arguments in paper, skip here for brevity.

Can also get this immediately using the right swampland conjecture

Emergent string conjecture [Lee, Lerche ,Weigand ‘18; Lee],

Every asymptotic limit (in less than ten dimensions) of string theory is one where

a) A tower of KK modes becomes light
b) A string and a KK tower become light with the same mass scale

Both of these are decompactification limits for our purposes

Note: does not have to decompactify all internal dimensions

d external dimensions

k asymptotically decompactifying internal dimensions

Accelerated expansion

For a single a canonical scalar ϕ whose potential asymptotically goes as

$$V \sim \exp(-\gamma\phi)$$

Acceleration is asymptotically forbidden if

$$\gamma \geq \frac{2}{\sqrt{d-2}} \equiv \gamma_{\rm acc}$$

For a multifield potential in a decompactification limit, we argue asymptotic acceleration is forbidden if just one of the fields obeys this bound.: Introducing more fields makes achieving acceleration harder
See Gary's and Flavio's talks and [Shiu, Tonioni, Tran '23] for exact statement and subtleties about when rigorous statements for multifield potentials exist

Decompactification limit

Consider d external dim, k internal dim with typical length R

Need V>0 for accelerated expansion

Positive V sources:

candidate	p-branes	l-form flux	curvature	loops
scaling in d dim BD frame	R^{p+1-d}	R^{k-2l}	R^{k-2}	R^{-d}

These may also scale with other parameters e.g. g_s, other cycles, but this will only make it more difficult to achieve accelerated expansion

Straightforward to rewrite in terms of canonical scalar ϕ volume modulus for our k internal dim

Flattest possible potential in d dimensions:

d+k dimensional cosmological constant

$$V \sim \exp\left(-\frac{2}{\sqrt{d-2}}\sqrt{\frac{k}{k+d-2}}\,\phi\right) \qquad \gamma < \gamma_{acc}$$

Next-Flattest possible potential in d dimensions:

Codimension-1 brane in d+k dim.

$$V \sim \exp\left(-\frac{2}{\sqrt{d-2}}\,\frac{k+d/2-1}{\sqrt{k(k+d-2)}}\,\phi\right) \qquad \gamma \geq \gamma_{acc}$$

Flattest possible potential in d dimensions:

d+k dimensional cosmological constant

$$V \sim \exp\left(-\frac{2}{\sqrt{d-2}}\sqrt{\frac{k}{k+d-2}}\,\phi\right) \qquad \gamma < \gamma_{acc}$$

Next-Flattest possible potential in d dimensions:

Codimension-1 brane in d+k dim.

$$V \sim \exp\left(-\frac{2}{\sqrt{d-2}}\frac{k+d/2-1}{\sqrt{k(k+d-2)}}\,\phi\right) \qquad \gamma \geq \gamma_{acc}$$

=> Accelerated expansion in d-dim. only possible with d+k dim. CC

Higher-dim scalar potential

One source V>0 did not consider:

scalar potential in the d+k dim theory

In order to get acceleration in d-dim need potential that accelerates in d+k dimensions [Rudelius '21]

Run argument iterative to fundamental dimension theory:

Can have scalar potentials in fundamental dimension string theory but these never accelerated

(O(16)xO(16) heterotic, massive IIA, supercritical string)

What is needed for asymptotic acceleration

D dimension	fundamental theory
$d+k<D$ dimensions	de Sitter vacuum
d dimensions	asymptotic accelerated expansion

Higher dimensional de Sitter vacua

Need higher-dim dS vacua for asymptotic accelerated expansion in 4D

Little work done (but see e.g. [Van Riet ’12; Andriot, Horer ’23; Cribiori, Montella ‘23])
Clearly getting higher-dimensional de Sitter vacua will be harder than 4D de Sitter vacua

$\Rightarrow$Getting 4D asymptotic acceleration will be even harder than getting 4D de Sitter vacua in the interior of moduli space.

One must get one’s hands dirty with the control issues of the interior of moduli space, asymptotics no way out

Forbidding 4D de Sitter?

By our conjecture:

Show 3D asymptotics no accelerated expansion

$\Rightarrow$No 4D de Sitter vacua in interior moduli space

(but then seems hard to completely analyse 3D asymptotics without knowing about 4D interior moduli space)

Trans-Planckian Censorship

d+k dim. cosmological constant gives

$$V \sim \exp\left(-\frac{2}{\sqrt{d-2}}\sqrt{\frac{k}{k+d-2}}\,\phi\right)$$

In d dimensions.

This gives accelerates but does satisfy (and for k=1 saturates) the Trans-Planckian Censorship conjecture [Bedroya, Vafa ‘19]

=>our conjecture implies the TCC in the asymptotics of moduli space, TCC is saturates if the interior of moduli space has de Sitter vacua

Summary

Asymptotic Acceleration Implies de Sitter Conjecture

Higher-dimensional de Sitter is necessary for asymptotic acceleration

Achieving accelerated expansion is as hard as achieving higher-dimensional de Sitter space

$\Rightarrow$Even harder than achieving de Sitter vacua in the interior of moduli space!

If one wants to study cosmology with accelerated expansion, the asymptotics of moduli space are no way around the control issues of de Sitter space