PROGRESS, CHALLENGES AND PROSPECTS OF THE SWAMPLAND PROGRAM

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Harvard

Strings: Geometry and Physics for phenomenology

Nov 8th 2021

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So **please interrupt me** at any point with questions, comments, remarks, thoughts, ideas… we are in no rush!!

Let's say we are interested in **quantum gravity**.

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$$\frac{1}{8\pi M_P^2}\int d^4x\sqrt{-g}\,R$$

Dimensionful coupling

$$M_P \approx 10^{19}\,GeV$$

Seems very out of reach… what to do?

Focus on **theoretical** problems (e.g. black hole evap.)

There's also **cosmology**

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$$\frac{1}{8\pi M_P^2}\int d^4x\sqrt{-g}\,R+\int\sqrt{-g}\mathcal{L}_{\rm EFT}$$

There are many consistent quantum field theories, that are fine on their own, but cannot be consistently coupled to quantum gravity.

- There is **evidence** that **not** every EFT can be consistently coupled to quantum gravity.

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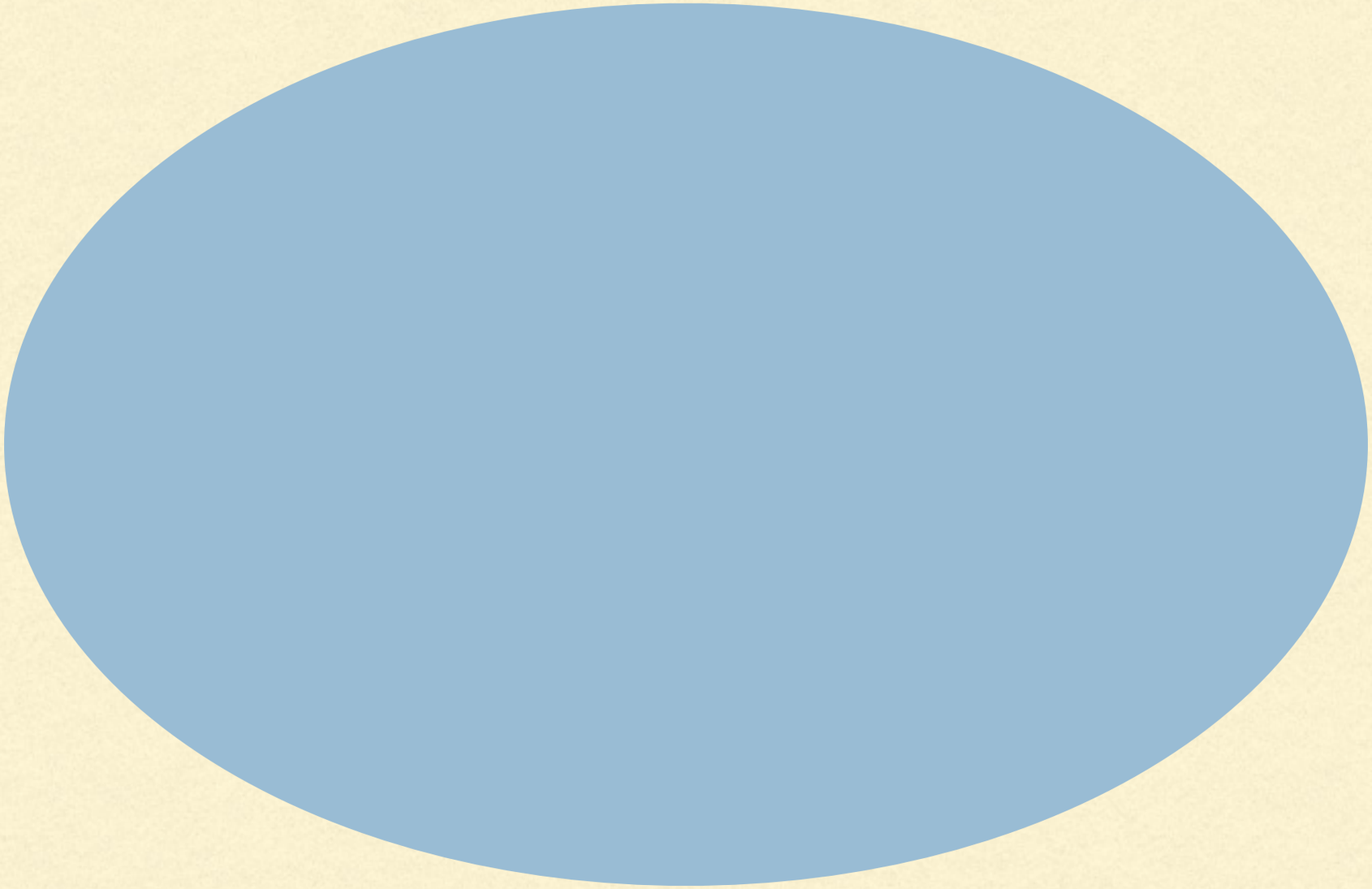

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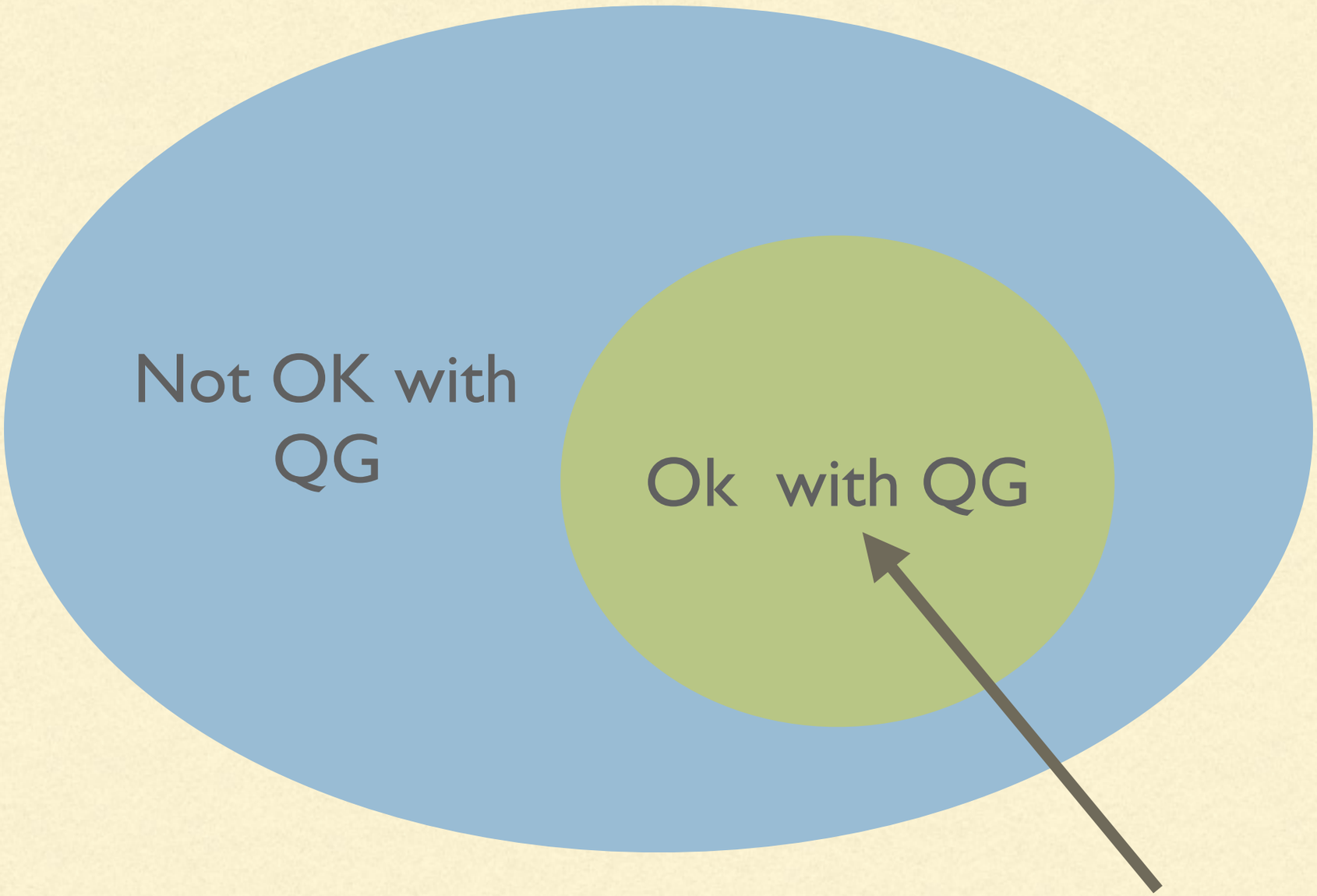

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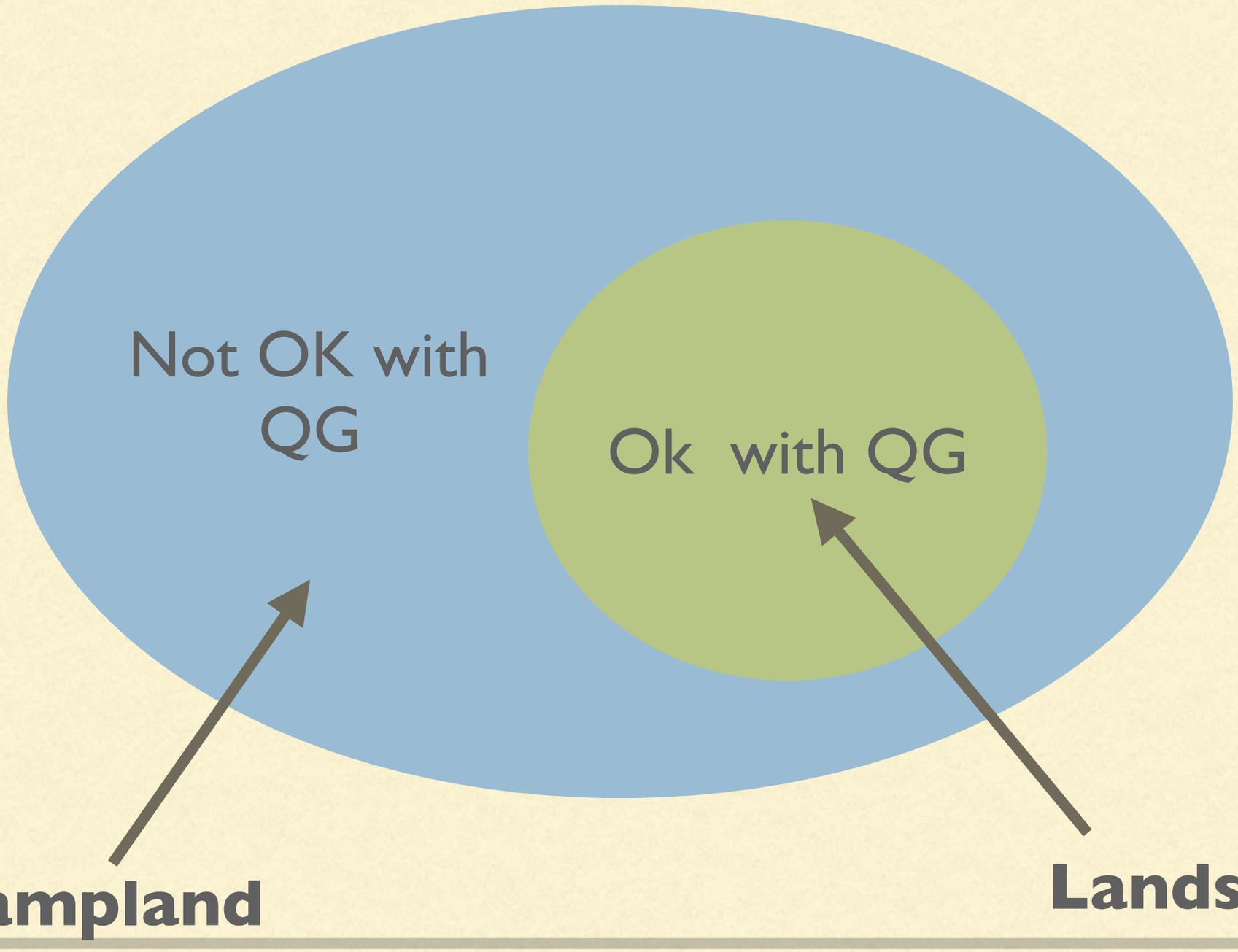

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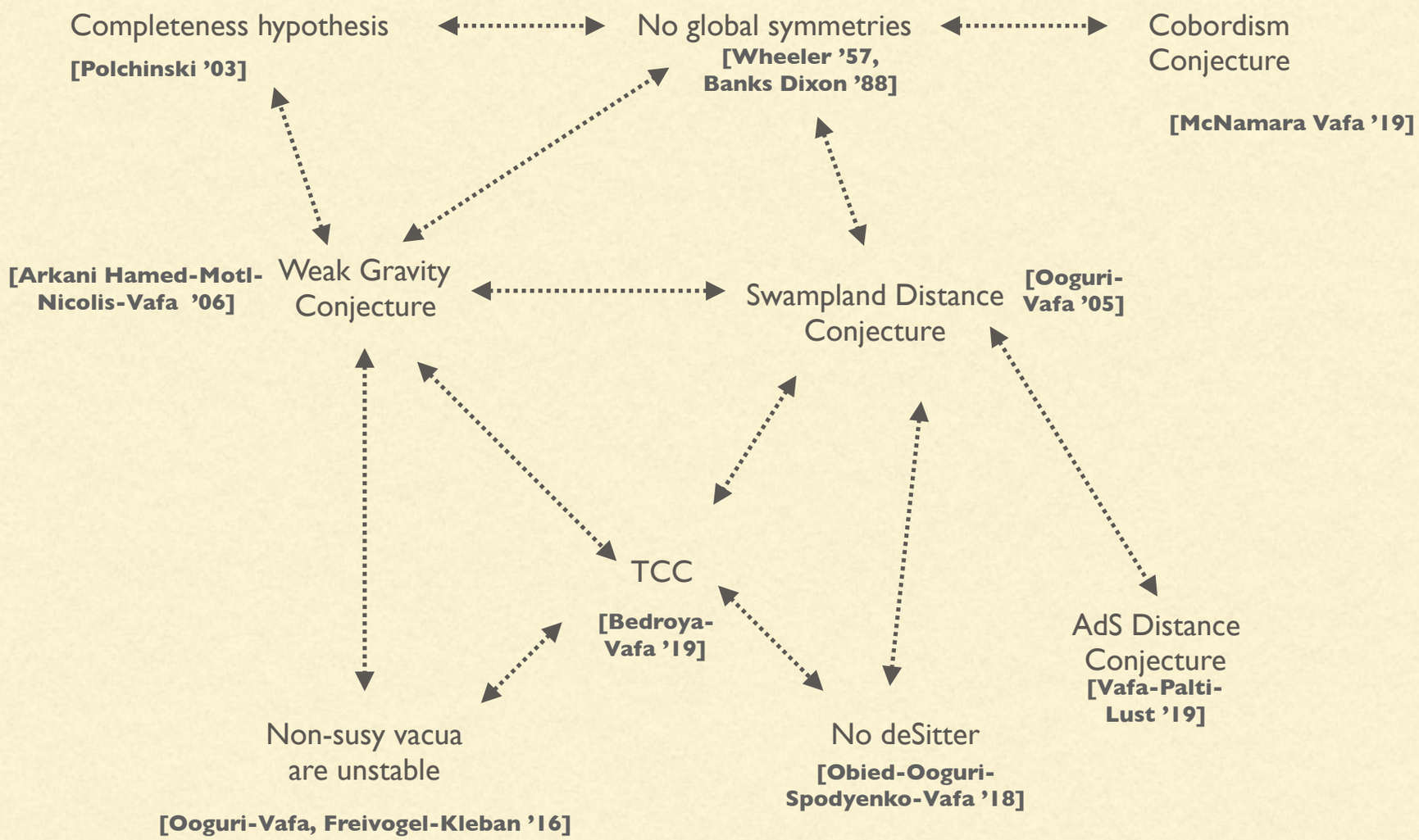
We organize this in a web of interconnected **conjectures**



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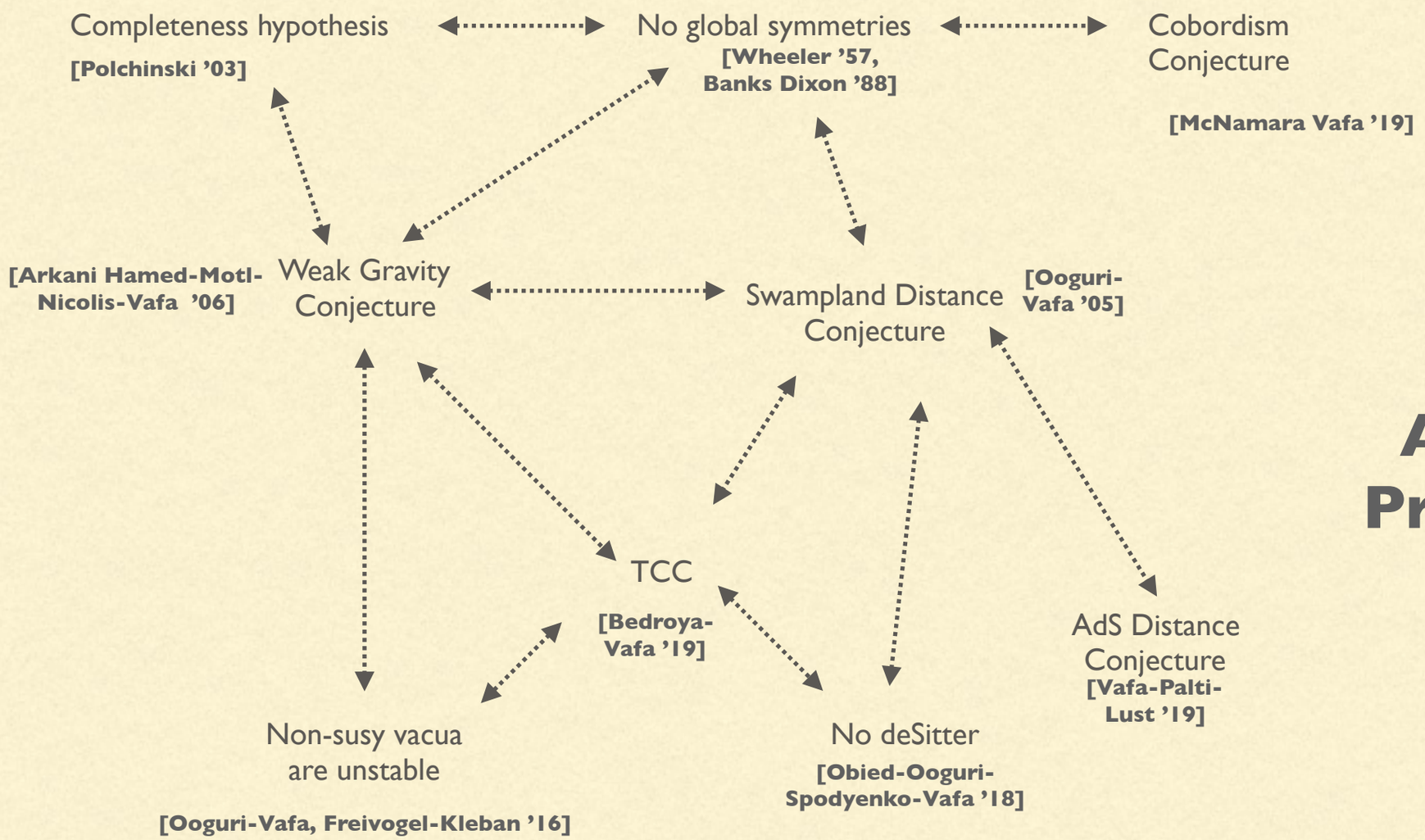

Prove
Check

Apply
Propose

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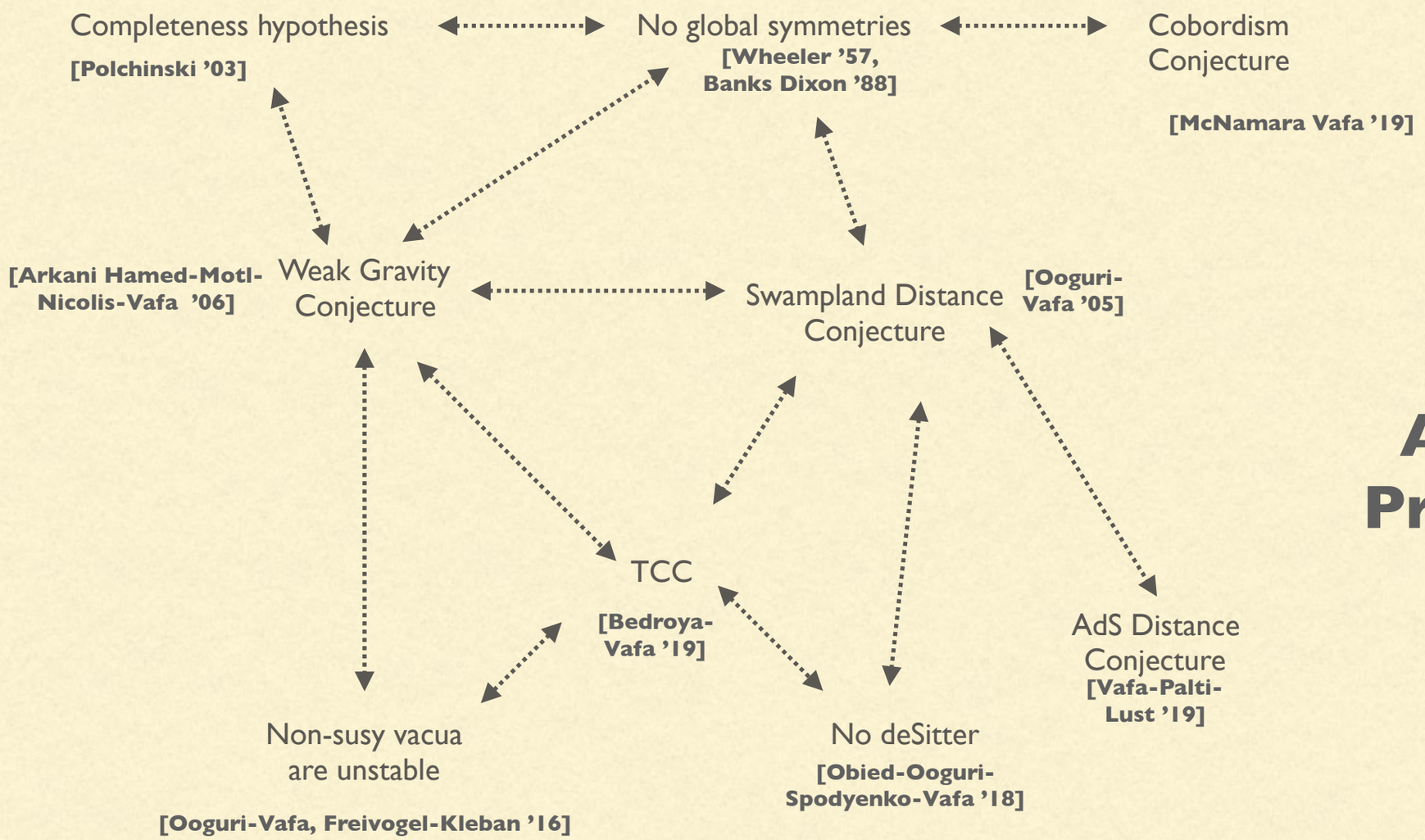

A good **review** on recent progress: See Irene's talk at Strings 2021 (lecture notes in 2102.01111)

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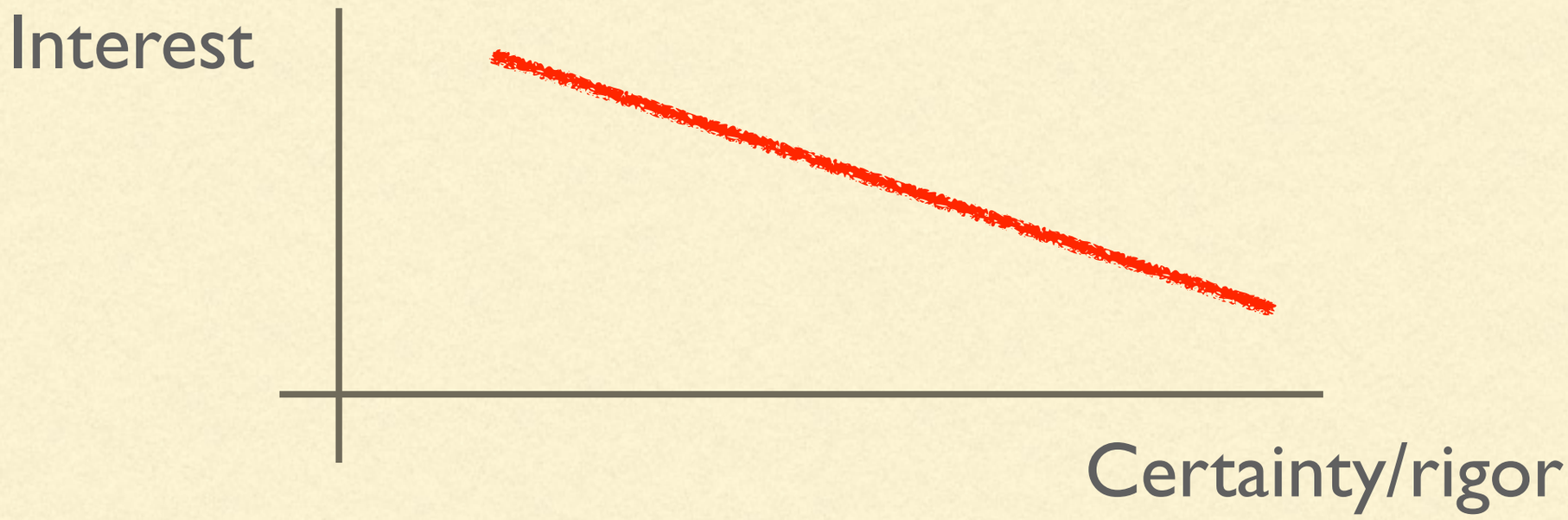

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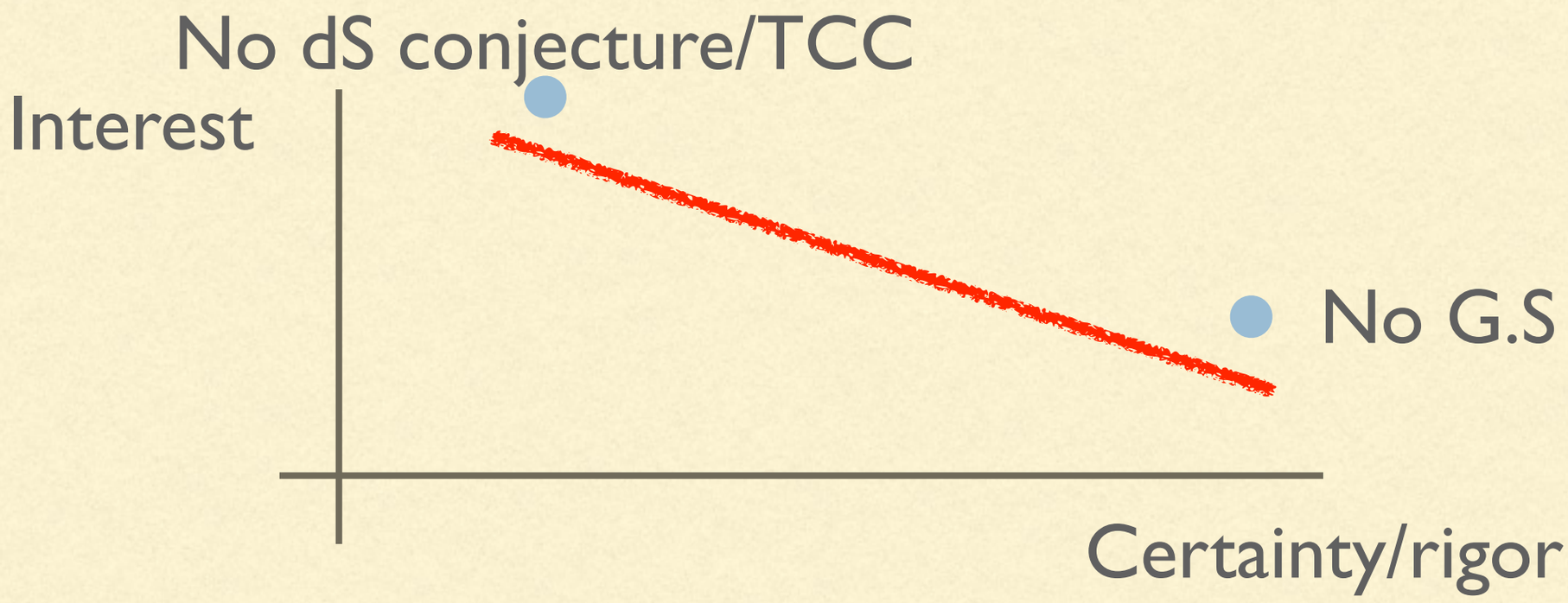
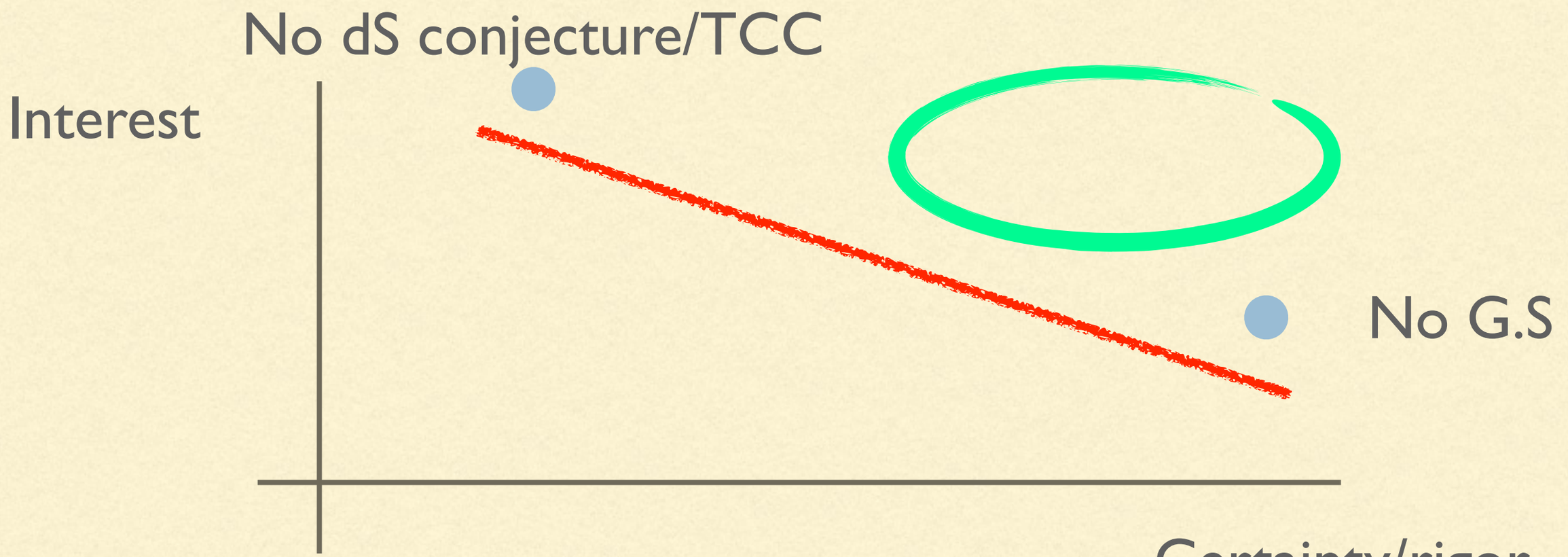


Challenge #1: How to access the interesting corner of the OHR diagram?



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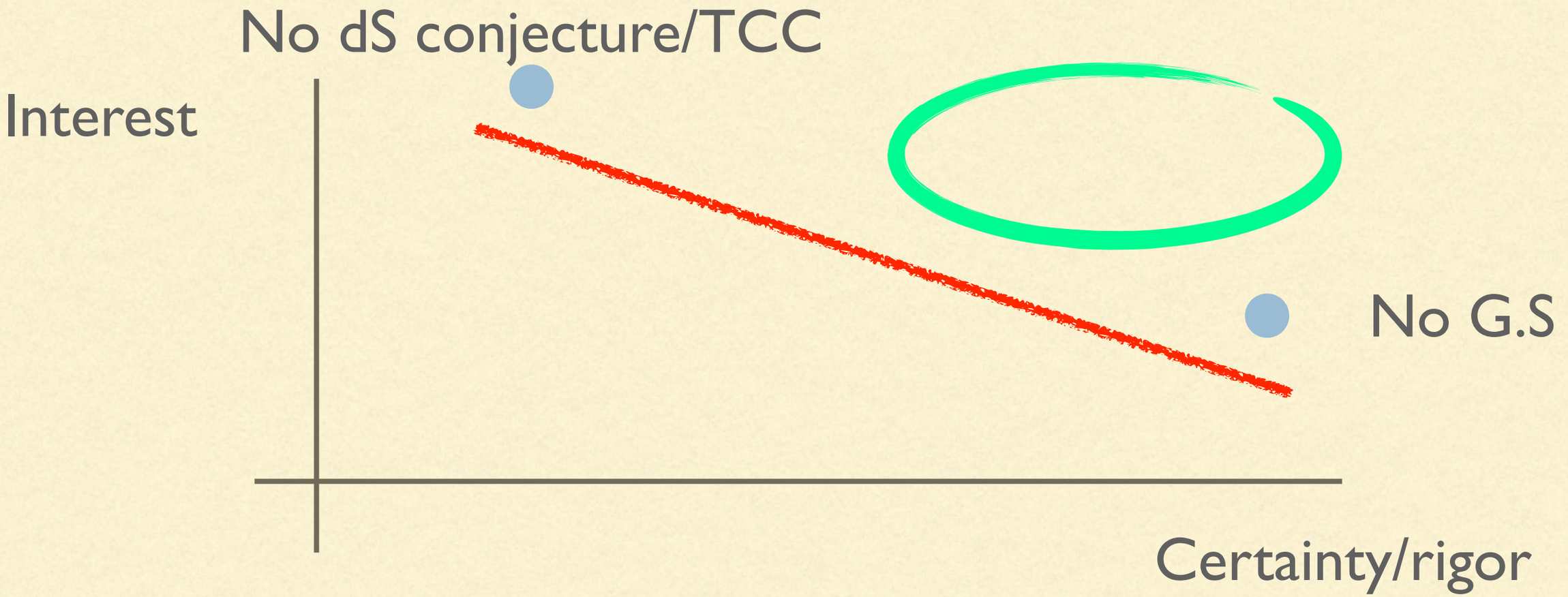

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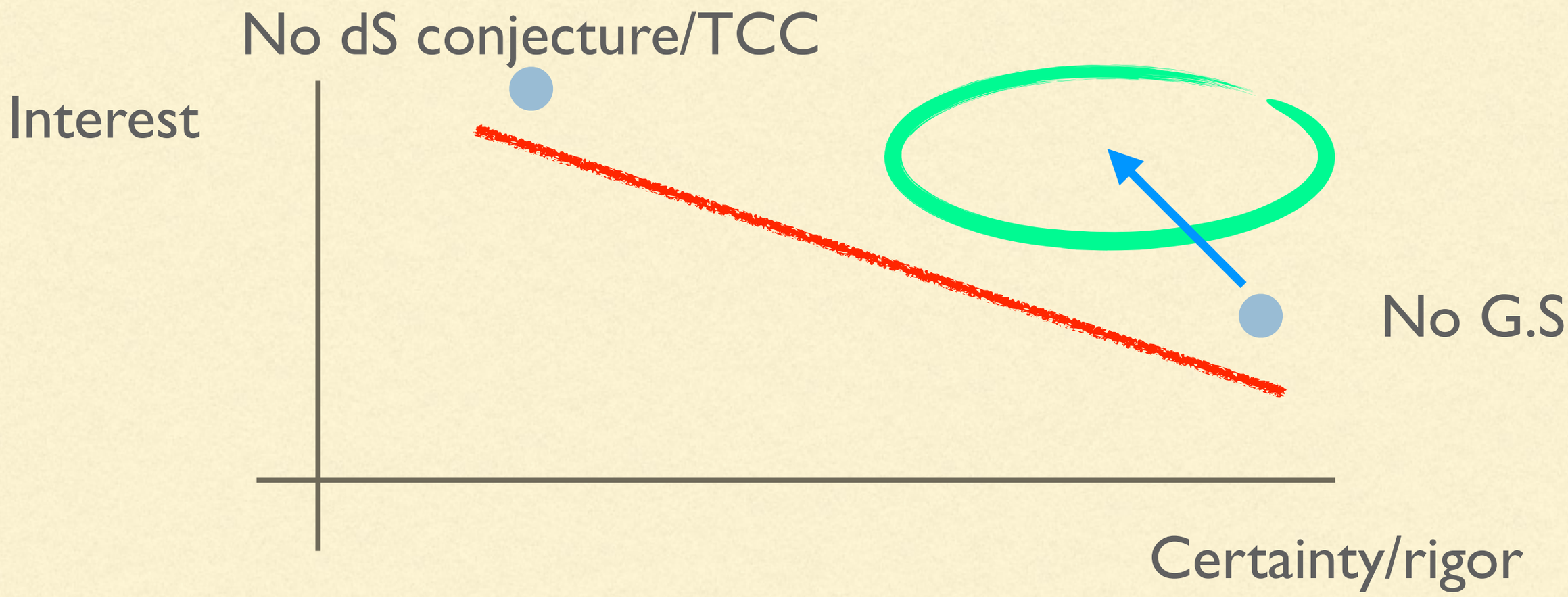

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(we have used Swampland principles to learn about ST in d>6!)

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- Can we argue any QG must have fermions?

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… but q<10 in known, SUSY flat space compactifications (can be more in AdS)

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How large can a discrete symmetry group be, given a cutoff scale?

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- Formulate Swampland questions rigorously, to attack them with the aforementioned techniques

Order of discr. sym in bulk

Order of discr. sym in CFT with gap to spin 2 primaries

How many light fields do we have before cutoff

Can one have pure QFT+gravity in large N until dimensions of order c?

Mass of WGC state

Dimension of charged primary

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In particular: **What is the dual of DGKT vacua?**

Must be a dead-end CFT, with no relevant deformations!

What can we learn from their 3d version?

Challenge #6: Make a concrete prediction for low-energy particle physics in our vacuum!

- Make a sharp prediction on inflationary field range/ tensor to scalar ratio

- Properties of particle physics/dark matter, like the FL bound $m^2 \geq g^2 q^2 \Lambda$

- Constraints on neutrino masses, and explaining coincidence with vacuum energy scale.

TO GET THE DISCUSSION STARTED

- Tools to effectively analyze scale-separated vacua such as DGKT, from either field theory or bulk sides?

- Concrete implications of the Swampland program for particle physics? Dark matter? Cosmology? neutrinos?

- Can extend the strong results of higher supersymmetry to cases with less SUSY?

- Can we bound how many massless fields can an EFT have?