THE FESTINA LENTE BOUND AND ITS PHENO IMPLICATIONS

Based on 2106.07650 with C. Vafa, T. Van Riet, G. Venken

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StringPheno seminars

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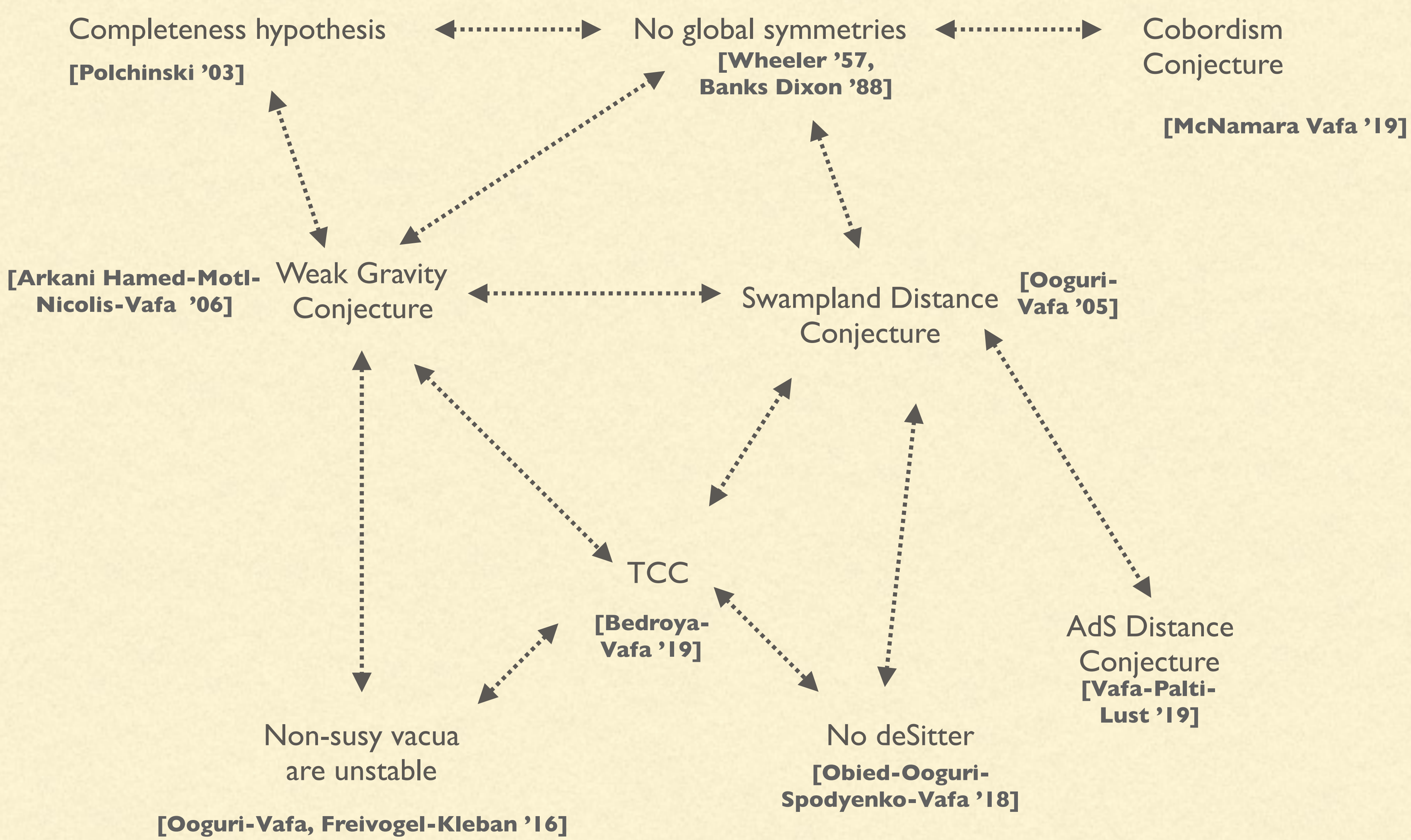
Main Swampland Idea: Ascertain **universal** features of quantum gravity

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



[See e.g. 2102.01111 by van Beest, Calderon Infante, Mirfendereski, Valenzuela '21 for the most recent review]

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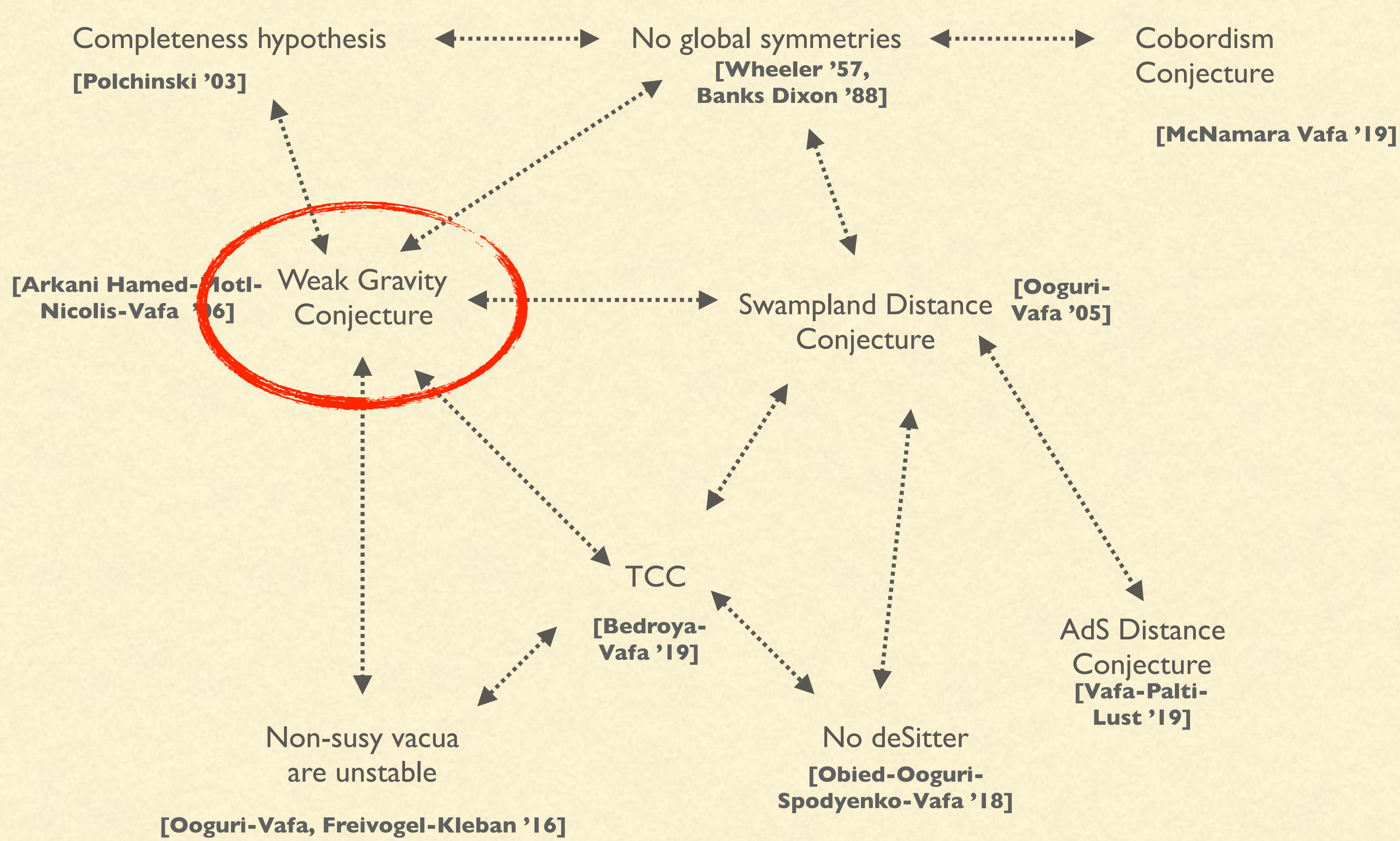

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Tried-and-tested
WGC
logic

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+

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Black Holes
w. positive vacuum
energy

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=

Festina Lente

[MM-Thomas Van Riet- Gerben Venken ’19, MM-Cumrun Vafa-Thomas Van Riet- Gerben Venken]

WGC:

[Arkani-Hamed, Motl, Nicolis, Vafa '06]

Any consistent QG with a U(1) **must** have charged states satisfying

$$m < \sqrt{2}\, q\, g M_P$$

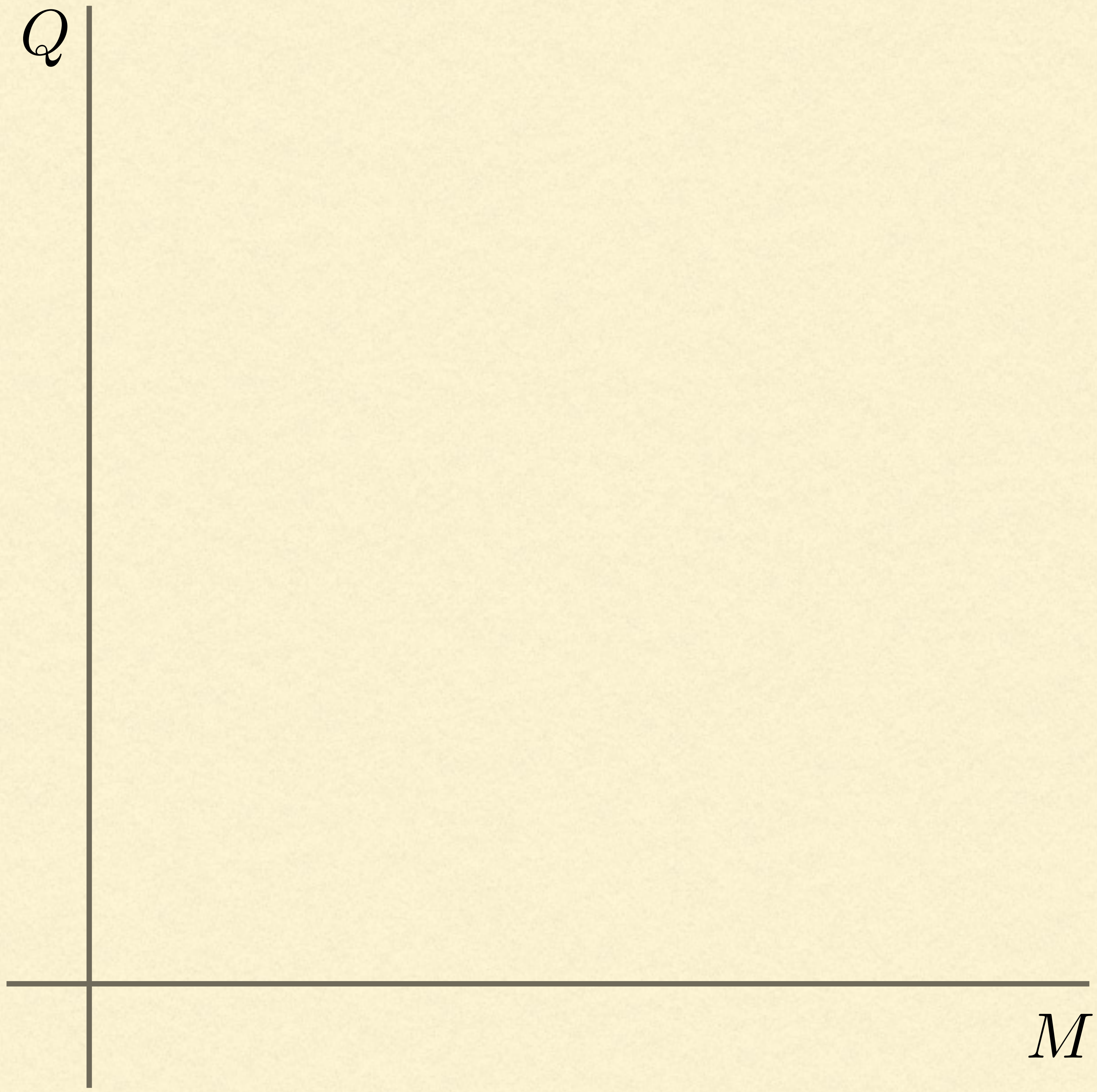
We have **extensive** evidence for this in String Theory.

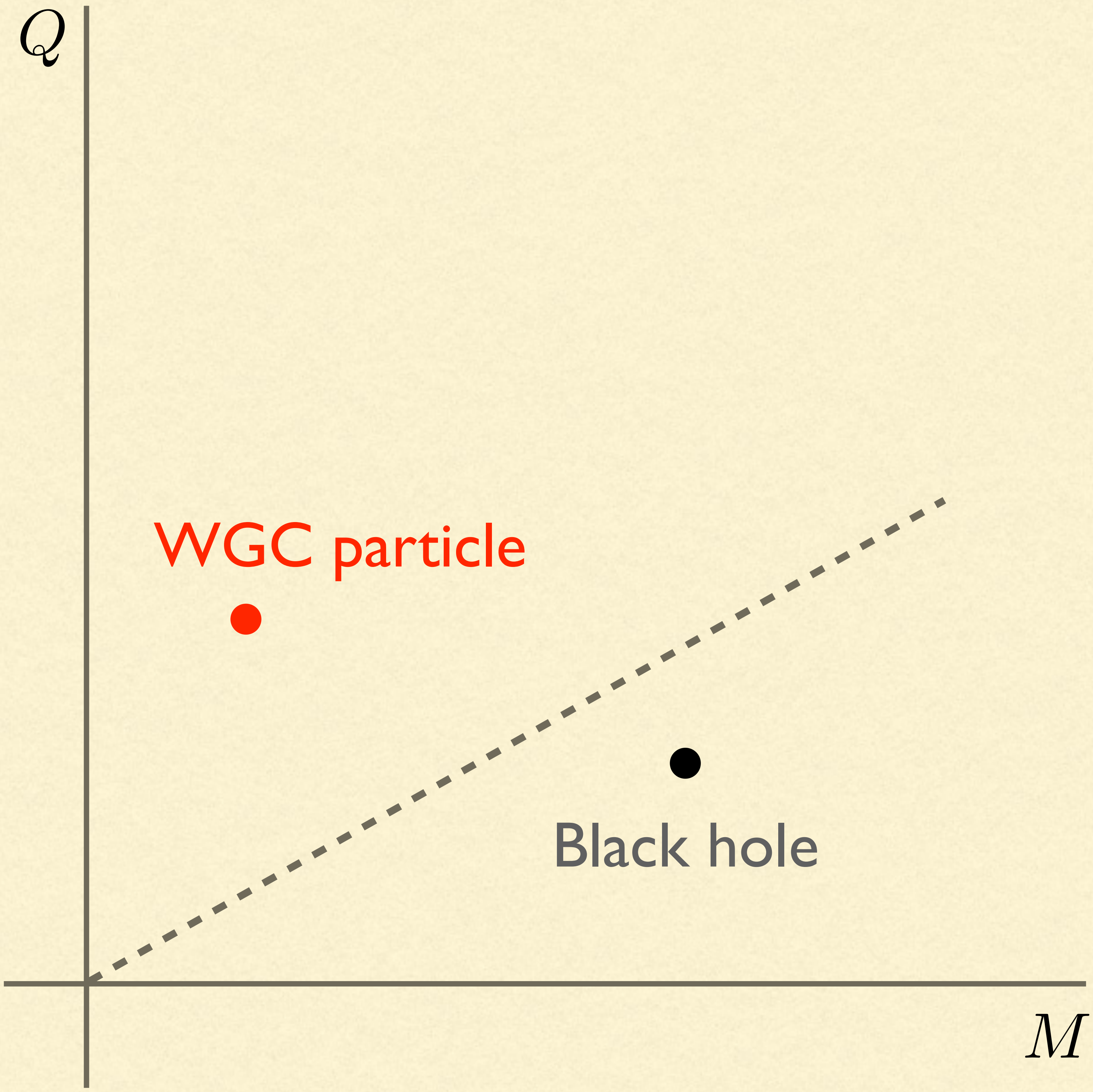
[Heidenreich-Reece-Rudelius '15,'16, MM-Shiu-Soler '16,Grimm-Palti-Valenzuela '18, Valenzuela-Gendler '20]

Why? Black holes decay **without becoming superextremal**

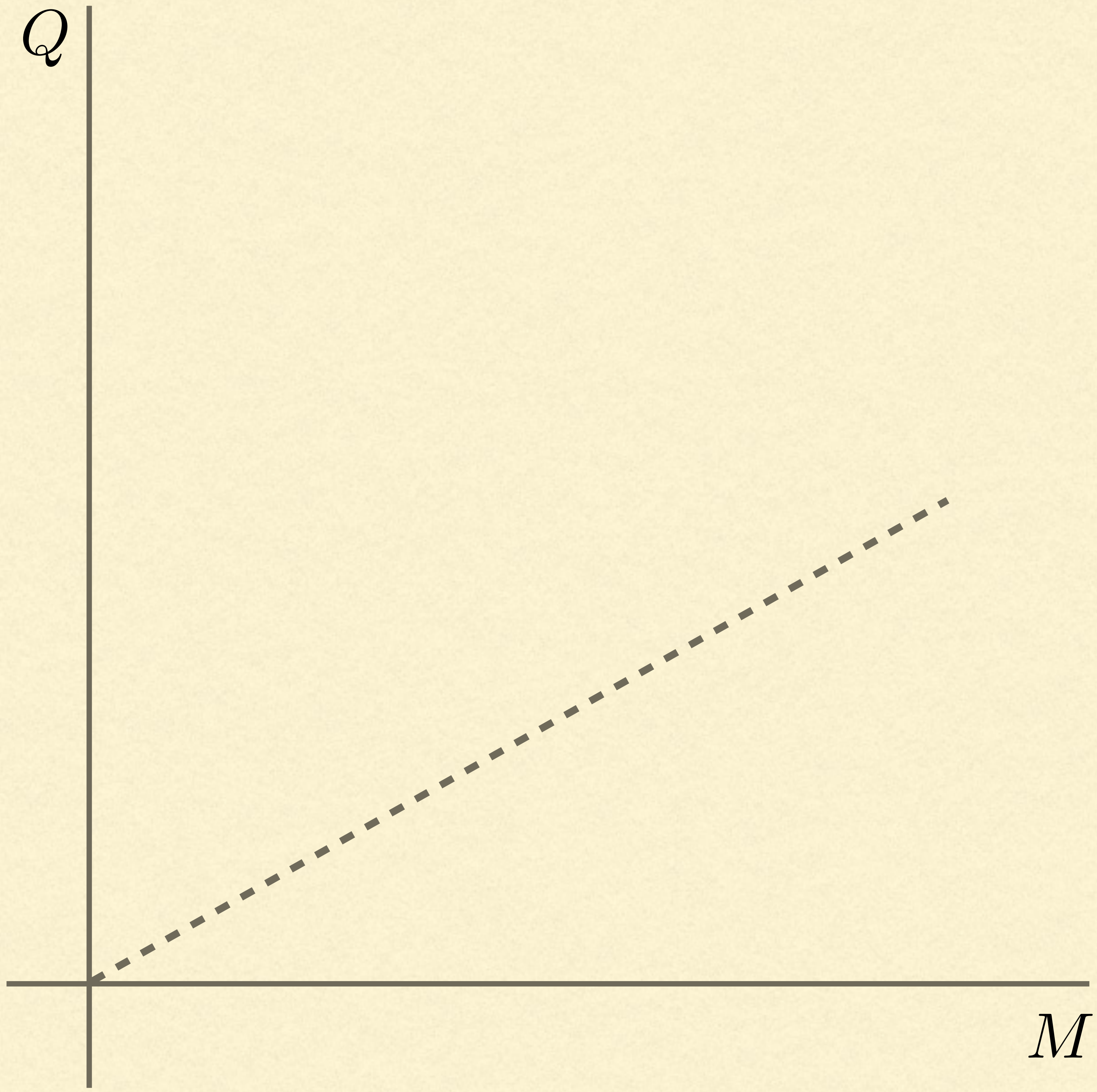
(No global syms, connection to cosmic censorship, ER=EPR)

[Santos-Horowitz '17,18, MM'18]


Q
M


Q
WGC particle
Black hole
M

So let's just do the same for **charged black holes in dS**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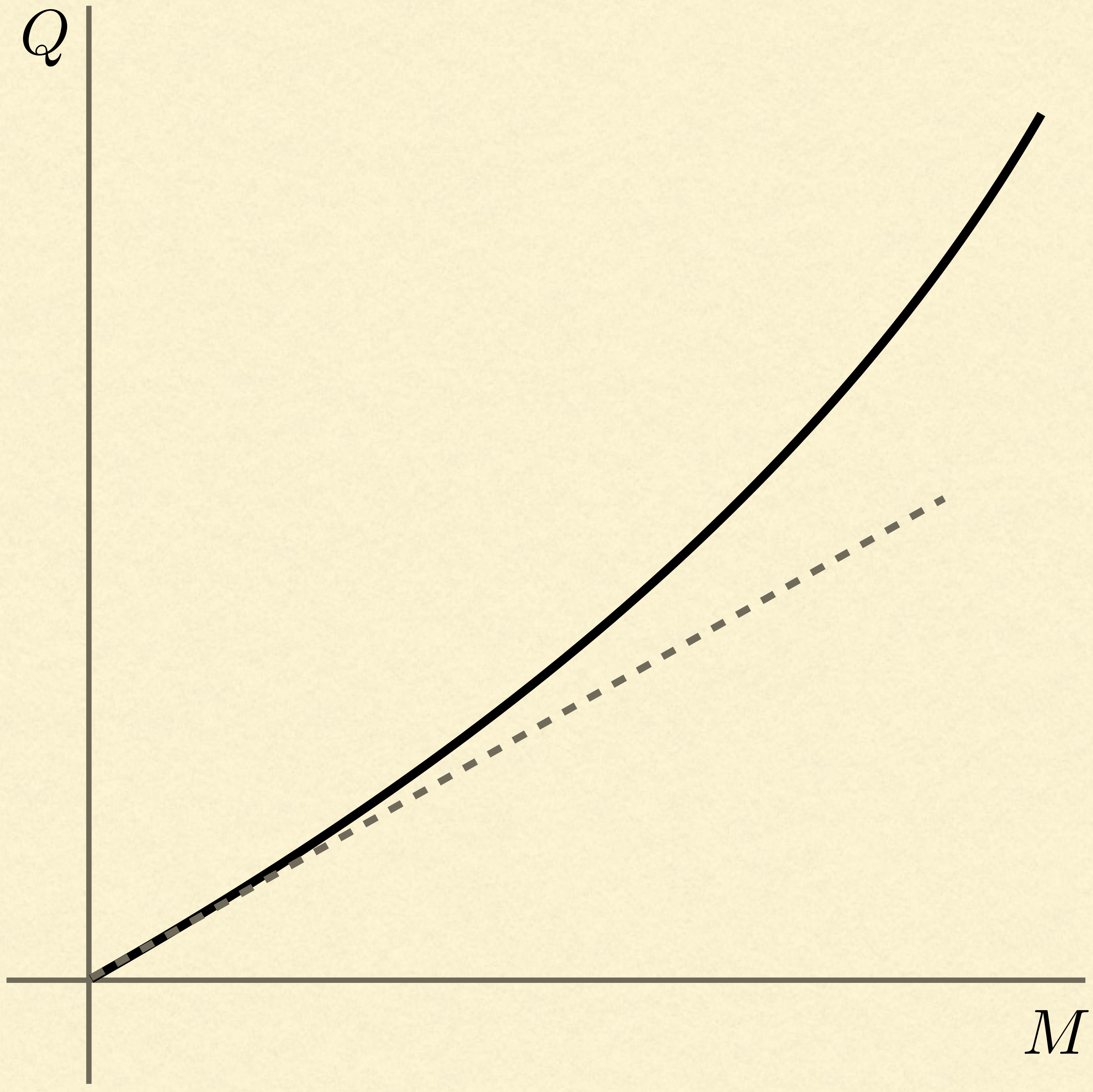
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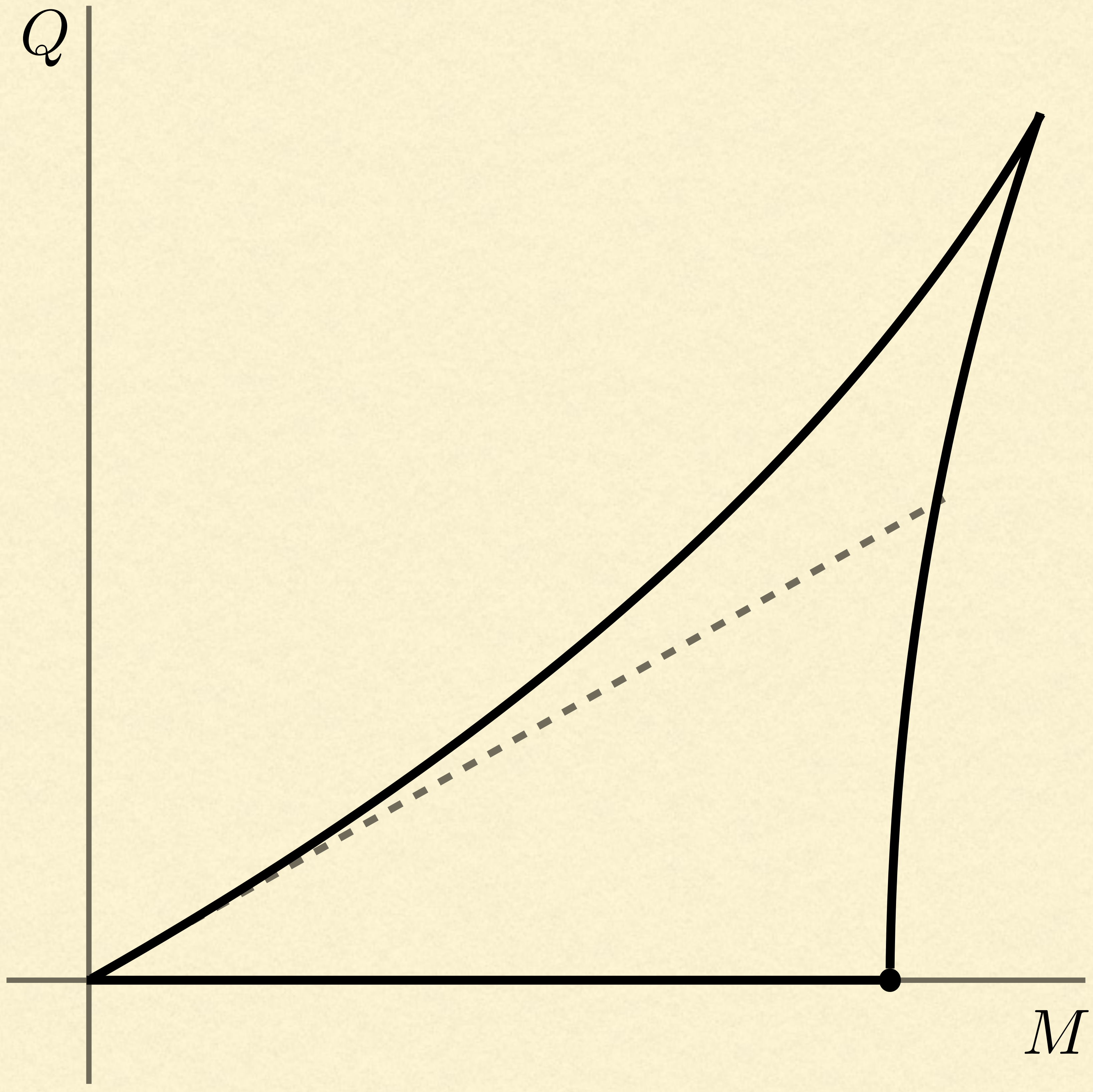

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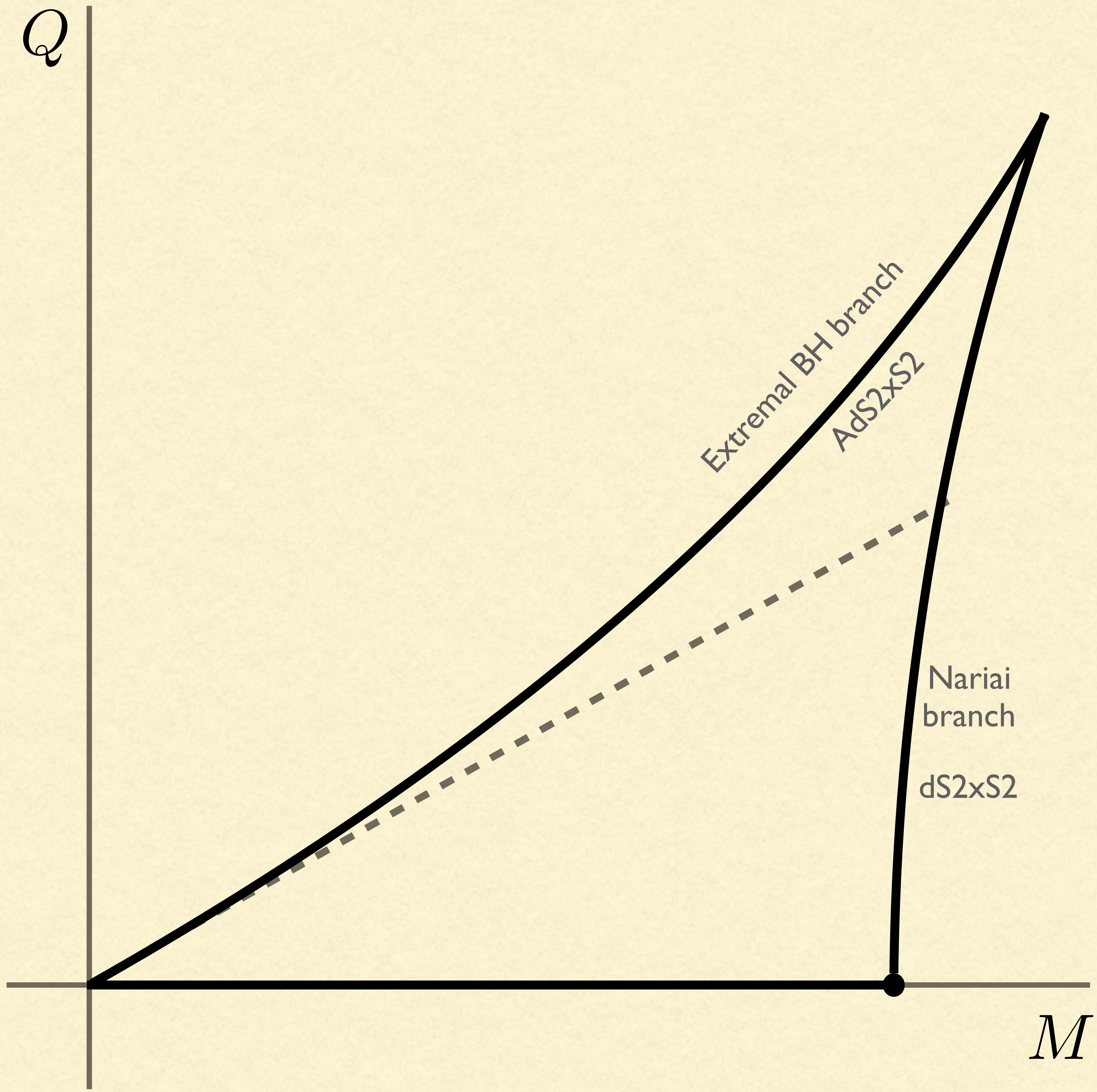
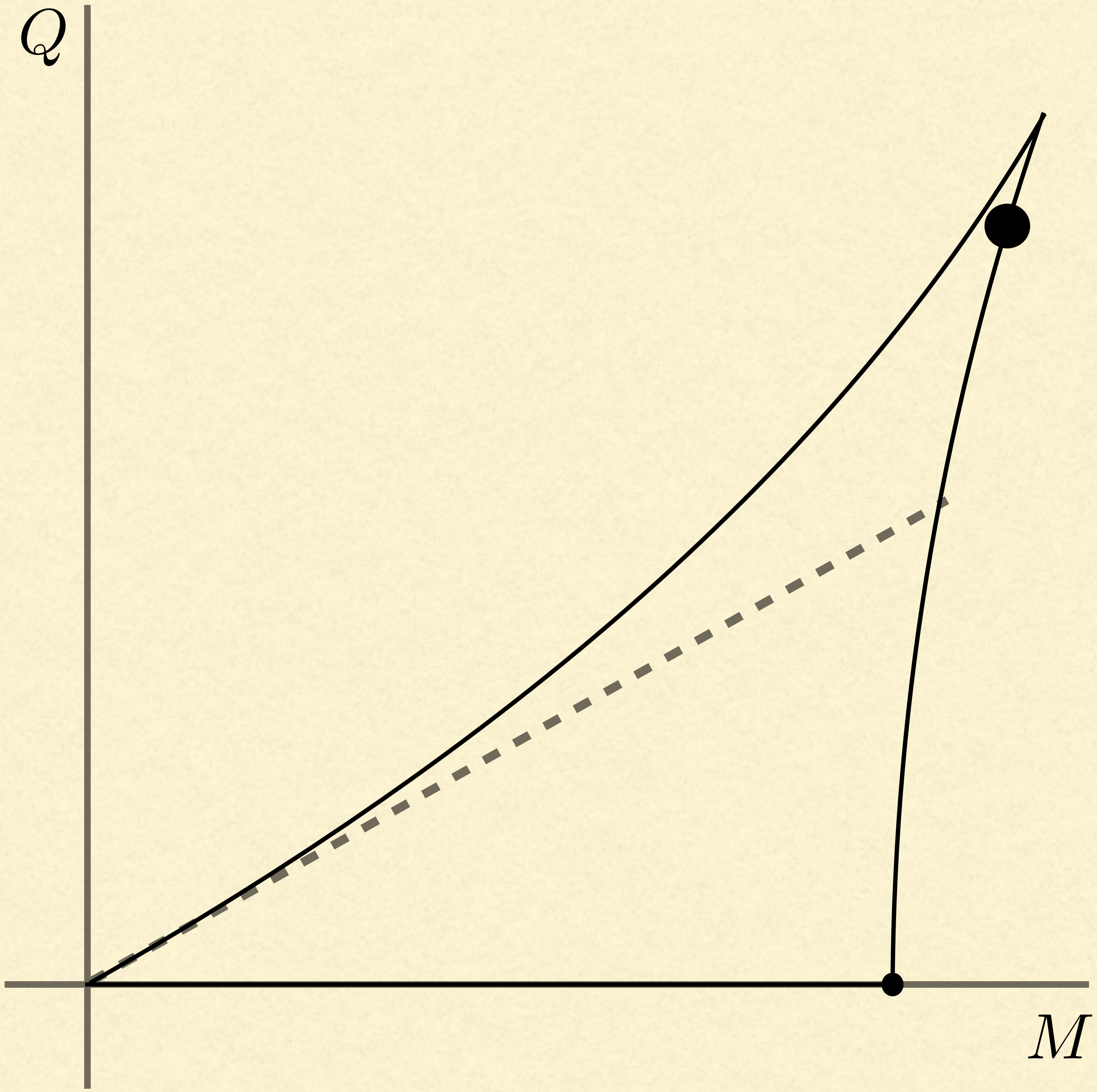
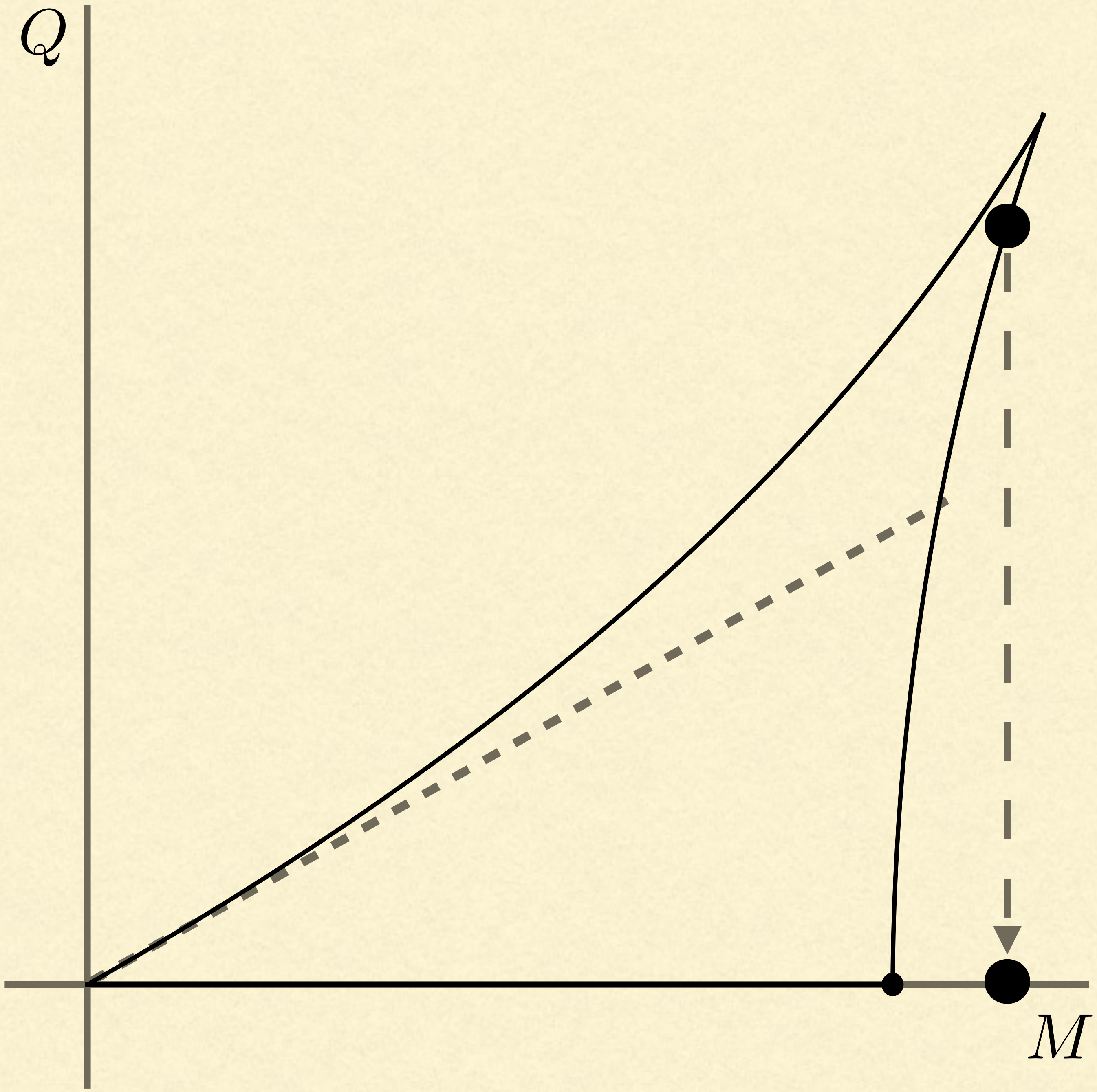


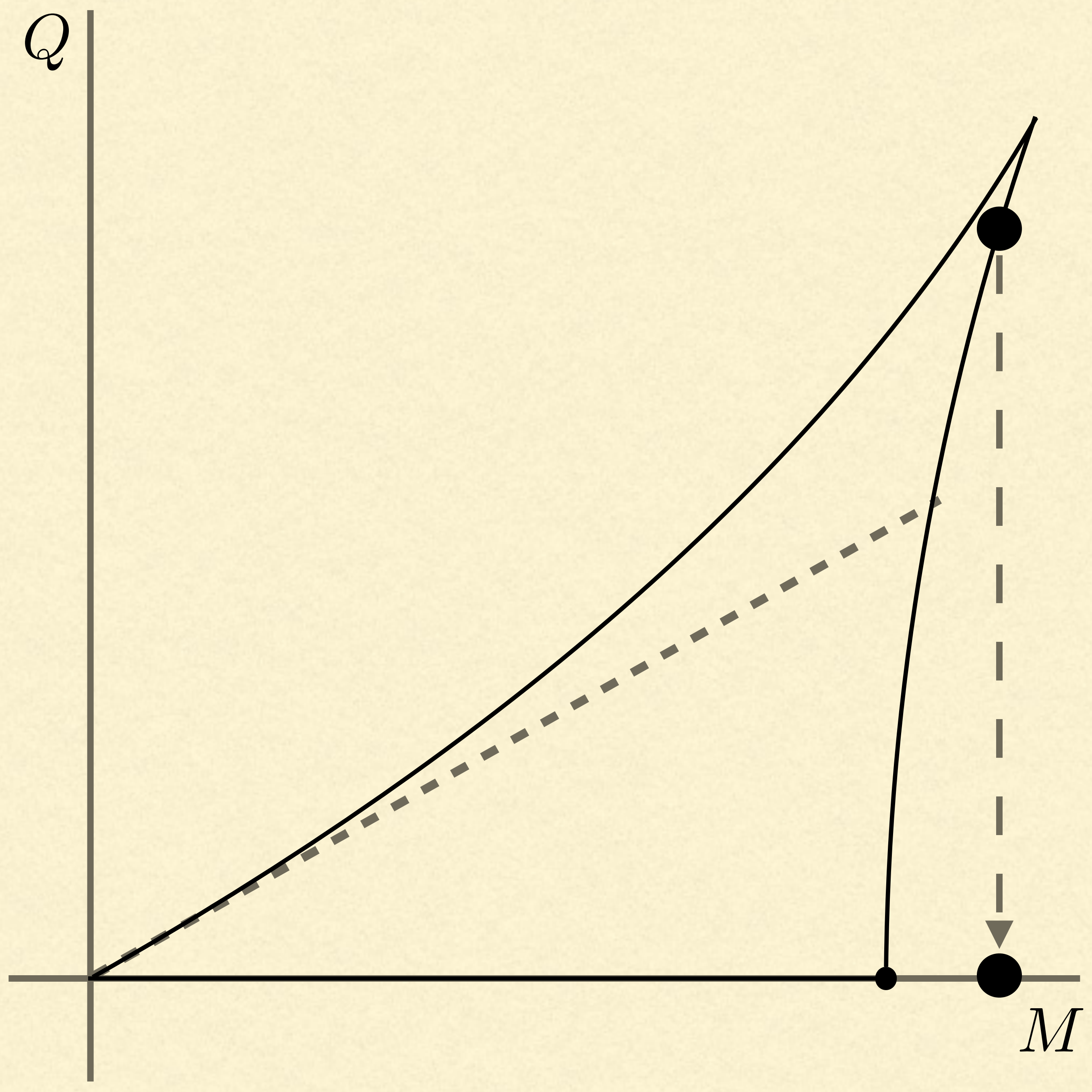
Q
Extremal BH branch
AdS2xS2
Nariai
branch
dS2xS2
M



Q
M



Black hole **can** become superextremal!



Black hole ~~**can**~~ become superextremal!

To avoid overextremal decay of largest Nariai, we must impose

$$\boxed{m^4 \gtrsim 2\, g^2 V}$$

for **every** particle in the theory.

This is the **Festina Lente** proposal (FL)

(latin phrase that translates to "Hurry up, but do it calmly")

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$$V = V(\phi), \quad g = g(\phi)$$

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$$f \equiv \frac{1}{g^2} \qquad\qquad \frac{V'}{V} \leq (d-3)\frac{f'}{f} \quad \text{and} \quad V'' \geq \frac{V'}{f'}\left(f'' - 2\frac{f'^2}{f}\right)$$

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but can be satisfied (in principle) in the bulk

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$m < \sqrt{2}\, q\, g M_P$ and $m^4 \gtrsim 2\, g^2 V$

together imply

$$g^2 > \frac{3}{2} \left(\frac{H}{M_P} \right)^2$$

which also **follows** from a **magnetic FL argument**

[Huang, Li, Song '06, Antoniadis-Benakli '20]

(just demand q=1 monopole is inside cosmo horizon)

It also behaves well under **dimensional reduction**

$$S = \frac{1}{8\pi G_{d+1}} \int \sqrt{|g|}\,(R - 2\Lambda_{d+1}) \ .$$

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We find FL is satisfied **at large radius** and also on a stabilized minimum provided that

$$M_{\mathrm{KK}} > V^{1/2}$$

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More generalizations (tower version, multi-U(1) fields) in the paper

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$$\Lambda \lesssim \frac{m^4}{24\pi\alpha M_P}$$

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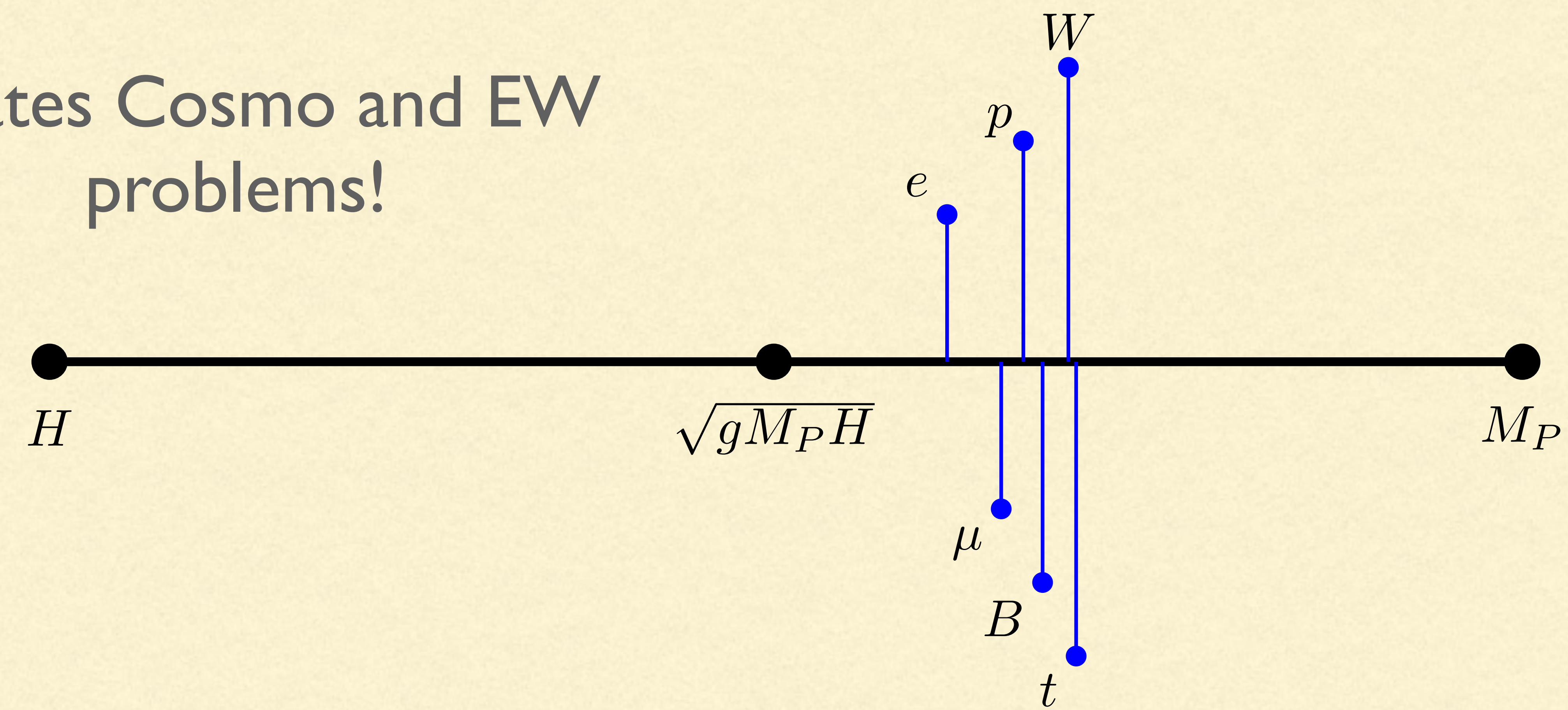

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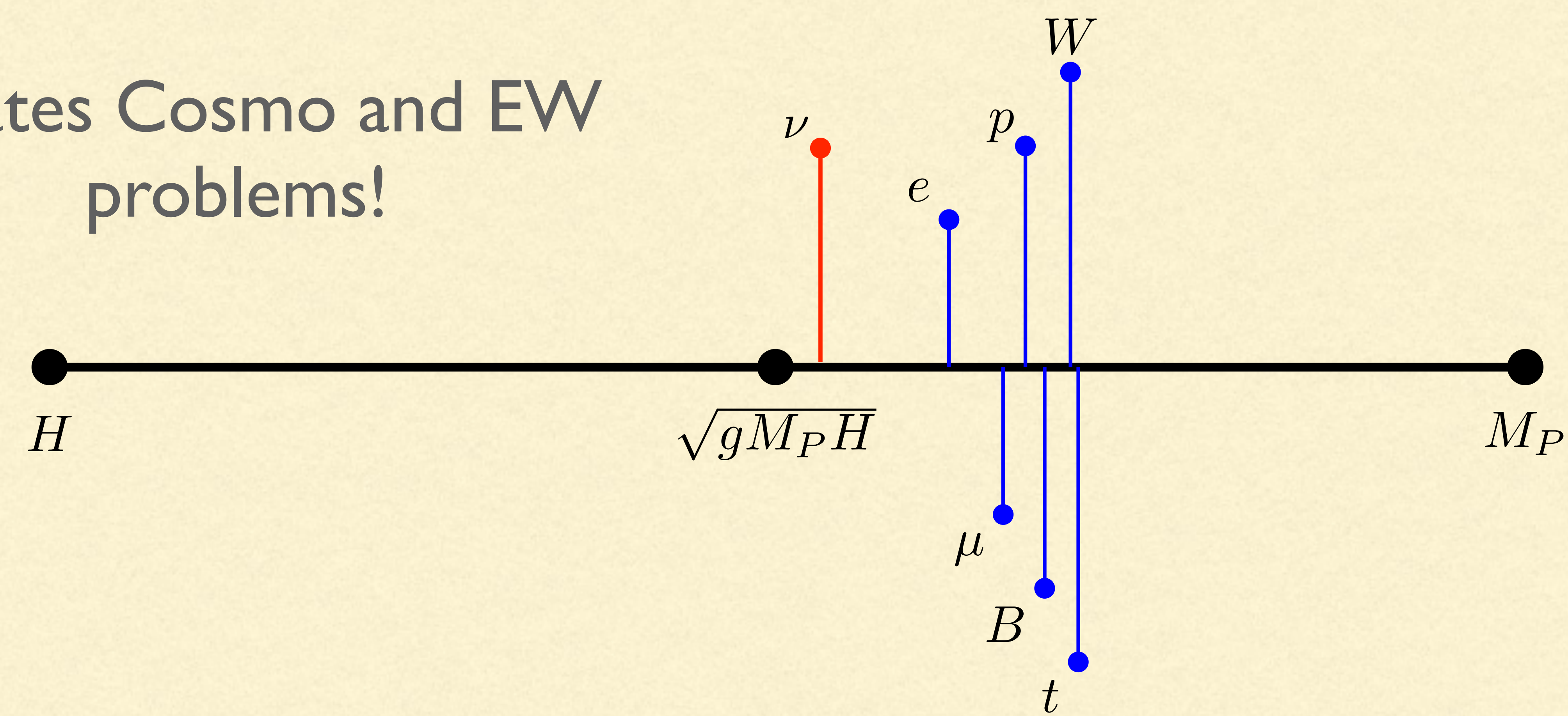

Neutrinos **almost** saturate the bound, but uncharged. Coincidence?

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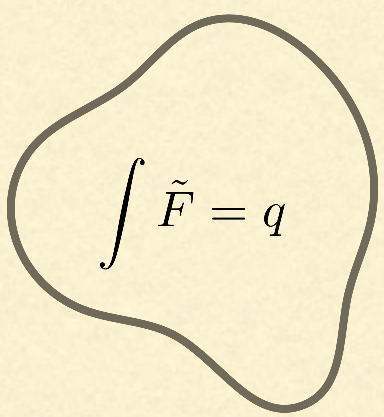

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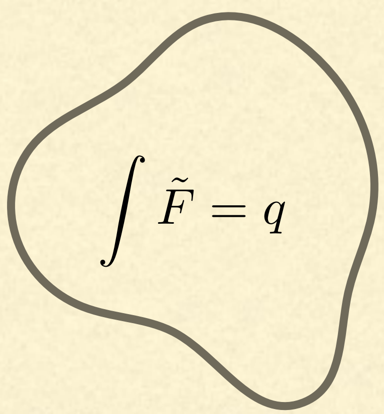

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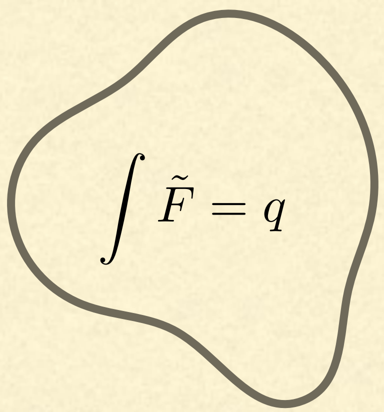

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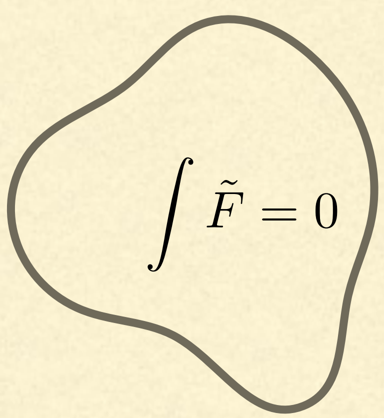

this scenario also leads to **neutral states** of similar mass

FL is also **in tension** with non-abelian gauge fields with

$$m \lesssim H$$

Predicts gauge fields must be **confined** or **Higgsed** above Hubble scale

$$\Lambda_{QCD} \sim 150\,\mathrm{MeV} \qquad m_W \sim 80\,\mathrm{GeV}$$

More generally, FL prohibits any phase of the SM with **unbroken EW symmetry** and low vacuum energy

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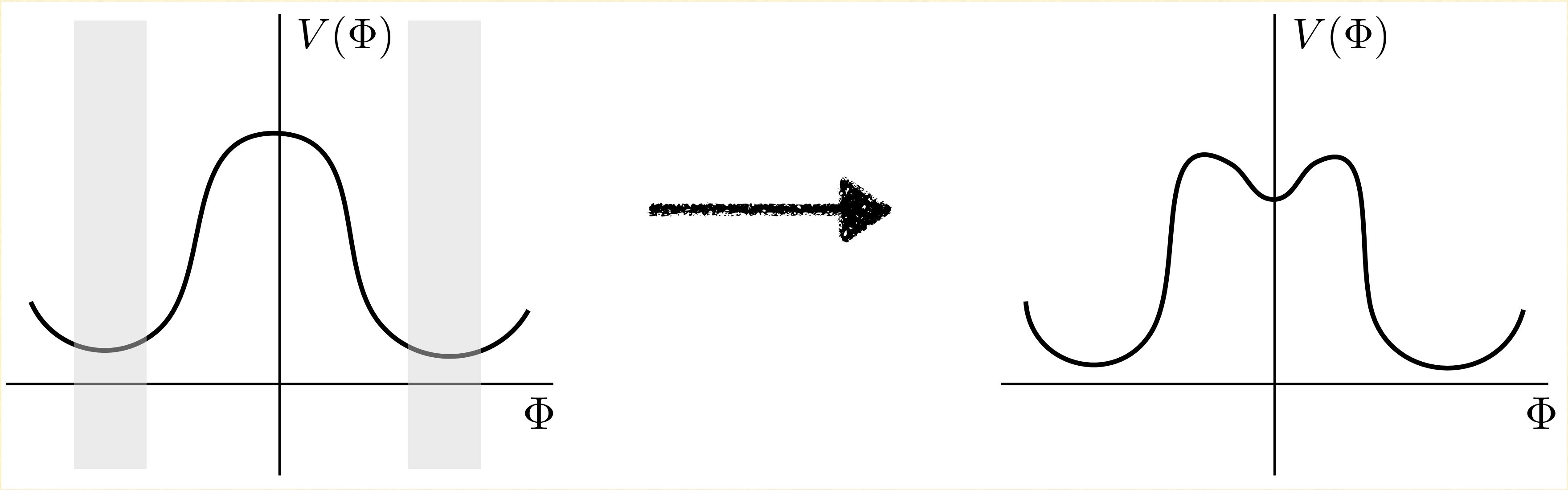

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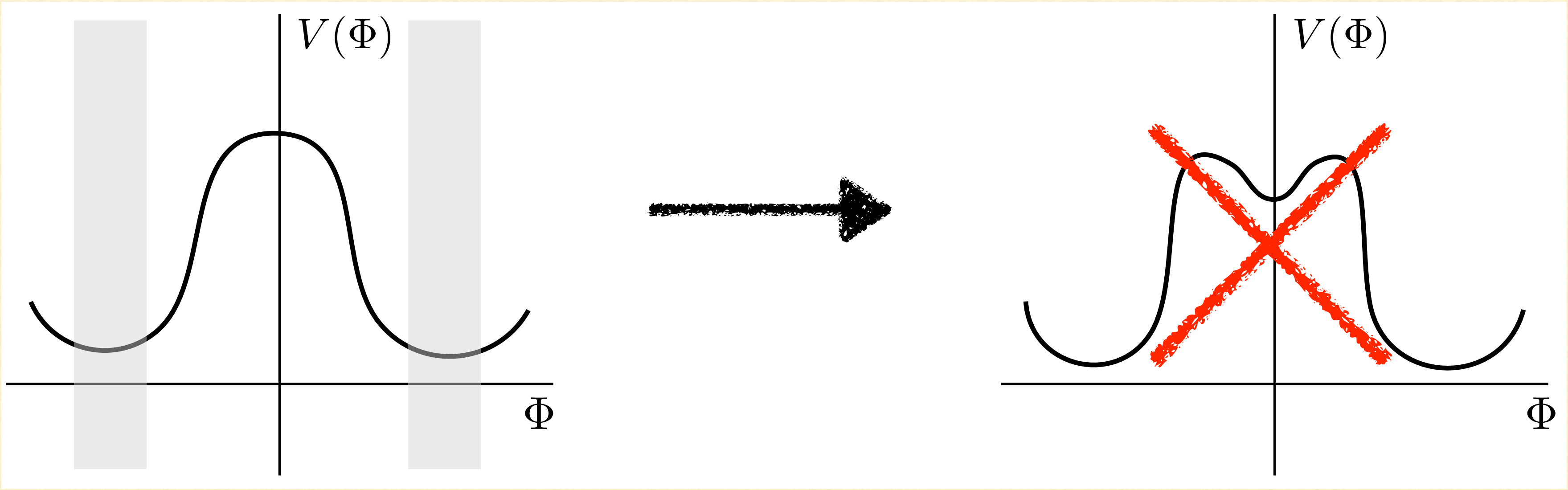
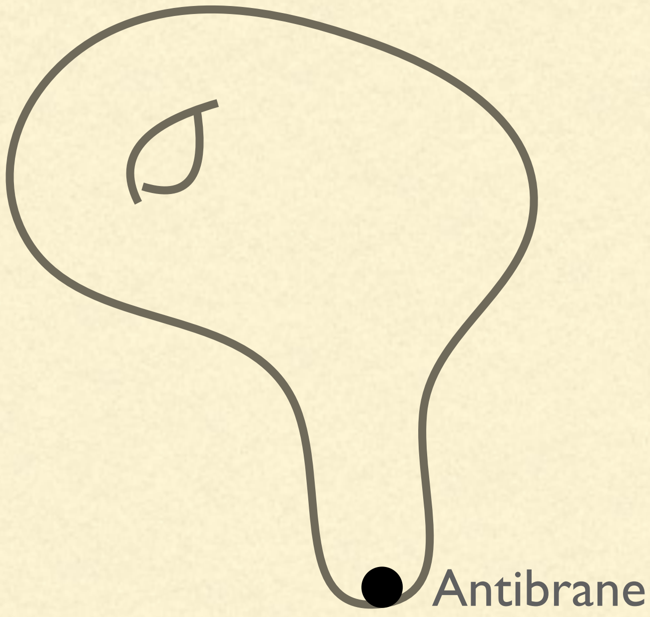


FL puts **bounds on the Higgs potential**

(Results compatible w. Ibañez, Gonzalo '18 from compactification of SM without Higgs to AdS3)



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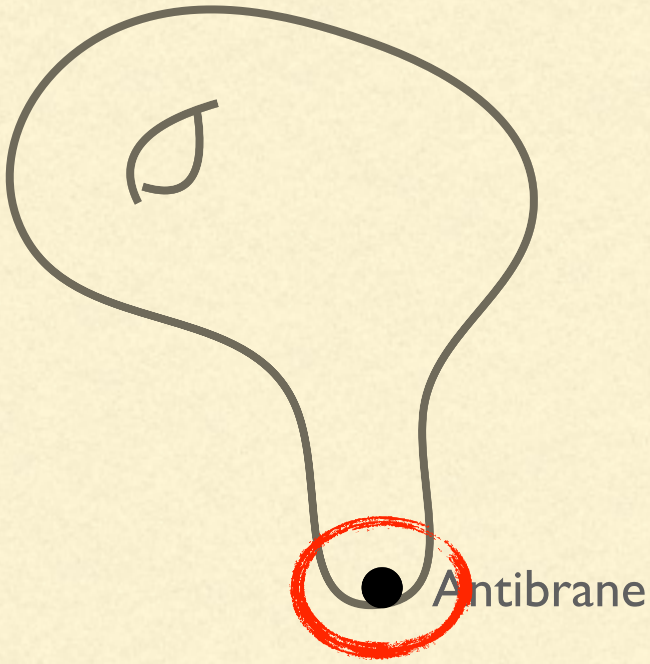

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Decoupled from the rest of the world

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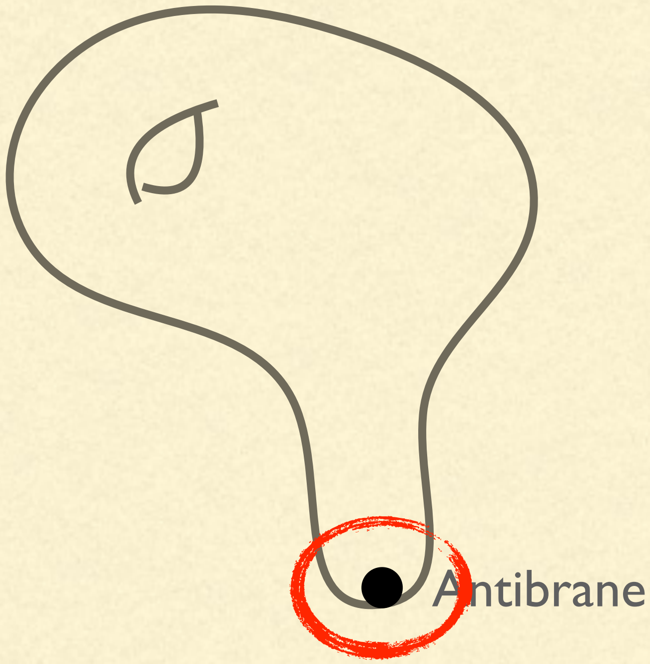
No Mp in the formula!

(with some assumptions) there is a **flat-space** version of FL



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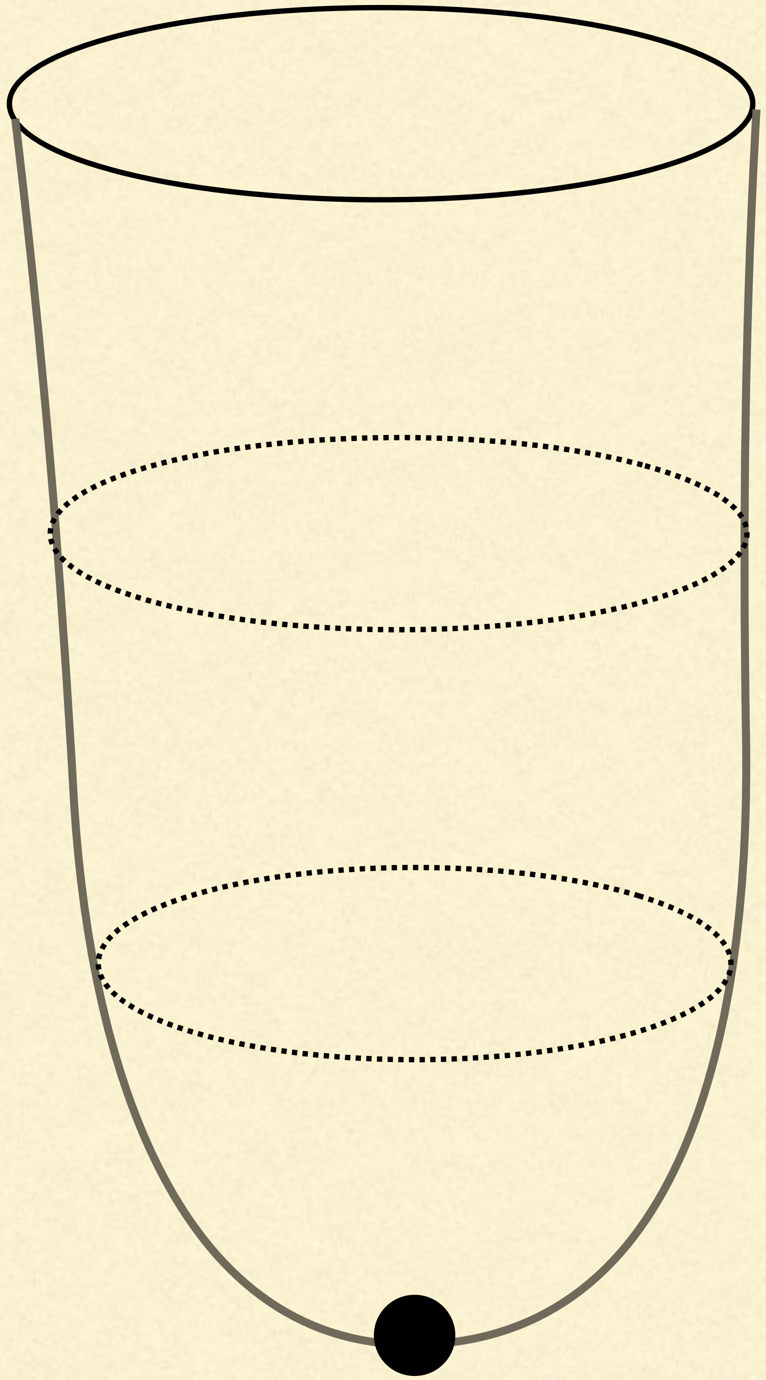
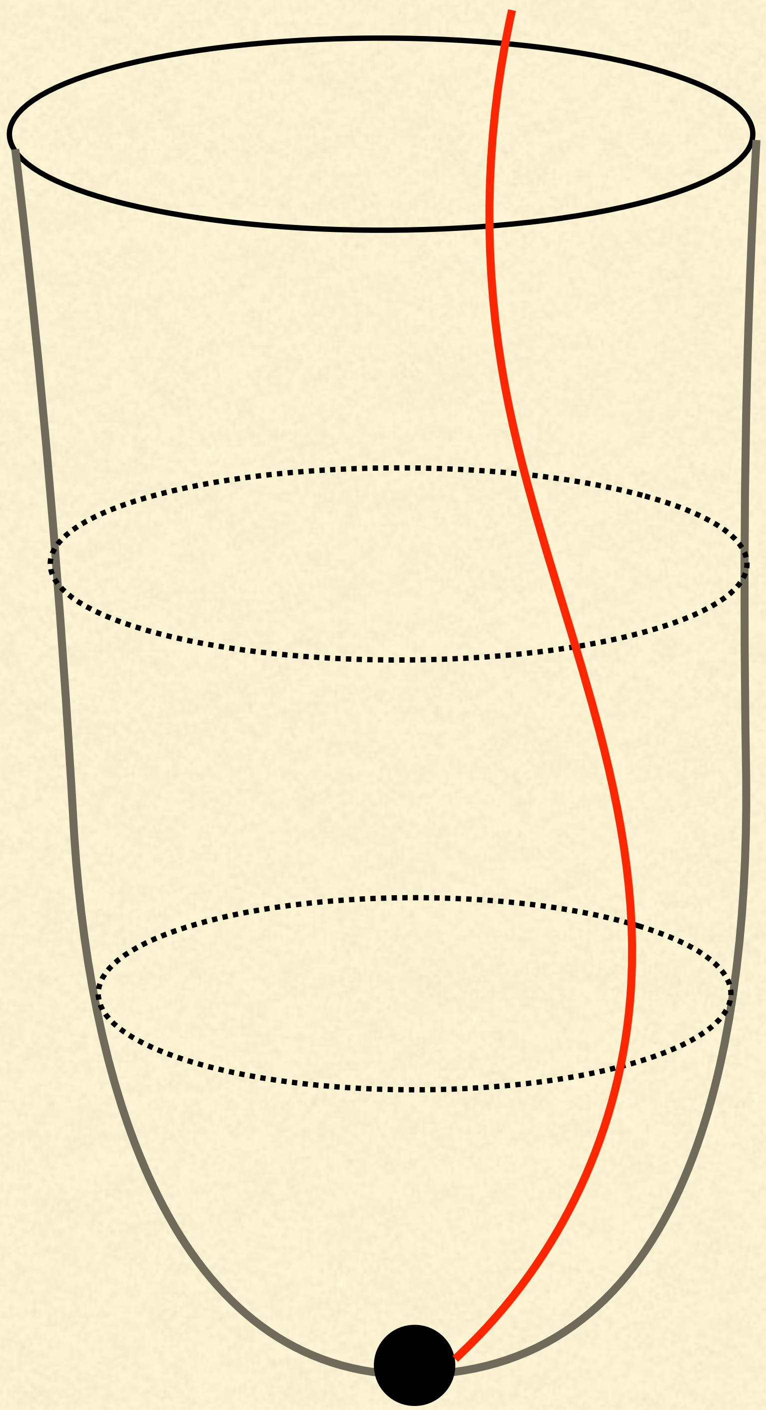
$$\mathcal{L}_{\rm DBI} \supset \int \frac{1}{2} |F - B|^2$$

Projected out by orientifold

There are **two kinds** of charged states



$$\int_A F_3 = M, \int_B H_3 = K$$



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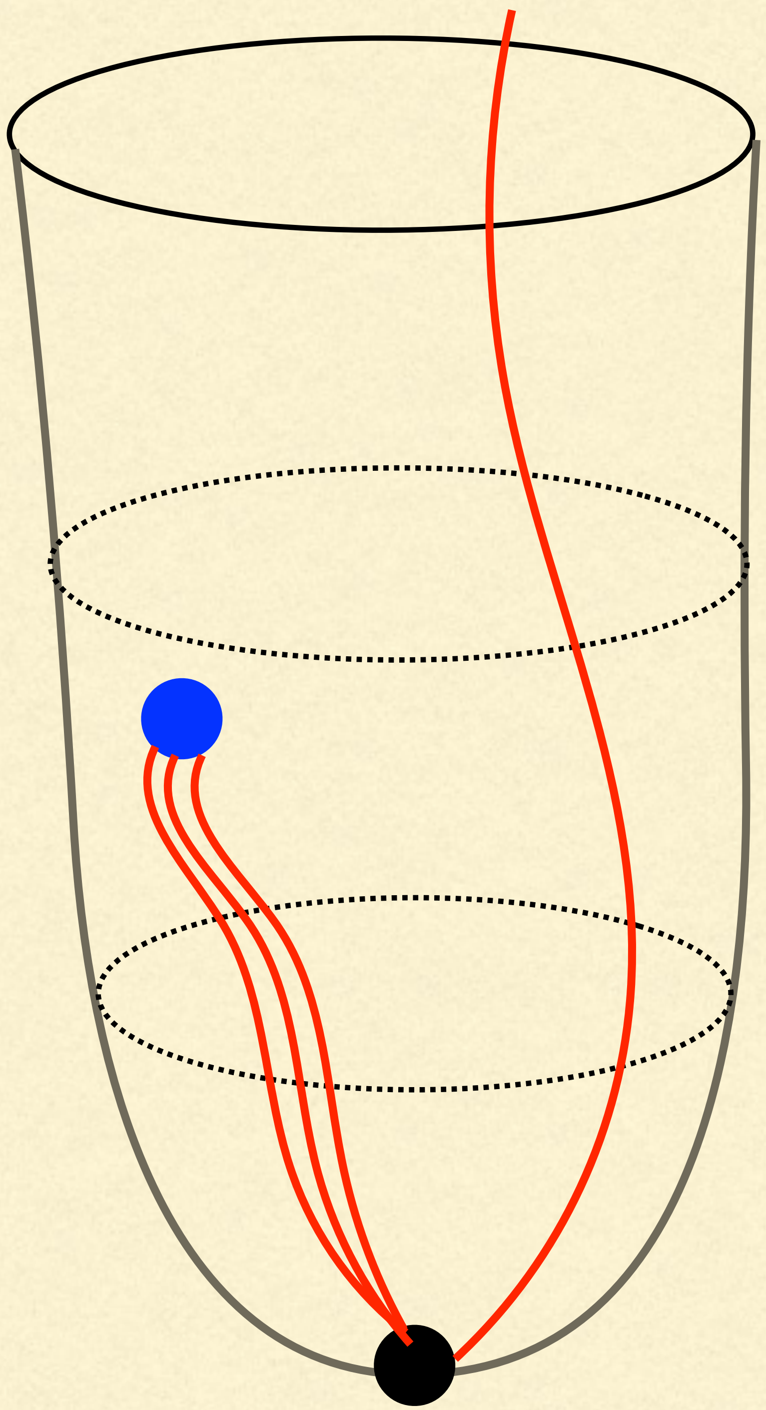
F1 strings that leave the throat



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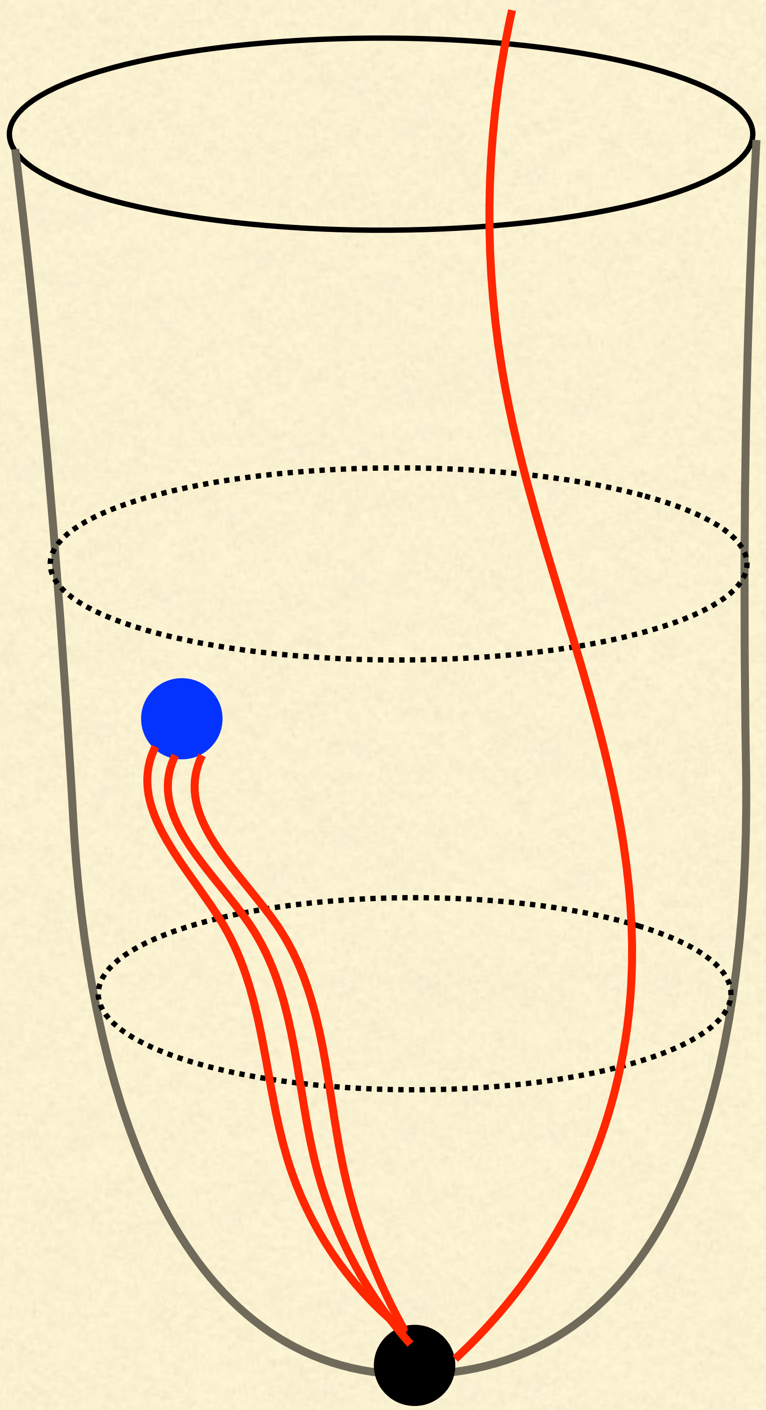

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FL and WGC amount to:

$$\sqrt{\frac{g_s}{\sigma}} L_t < 1. \qquad e^{-\frac{2\pi K}{3 g_s M}} < \sqrt{\frac{4\pi\sigma}{g_s}}$$

$$\frac{r_0^4}{g_s} e^{-\frac{r_0^4}{g_s}} < 1 \qquad (g_s M) K^{1/2} \gg 1$$

All these are satisfied!

So **antibrane uplift** complies with both constraints.

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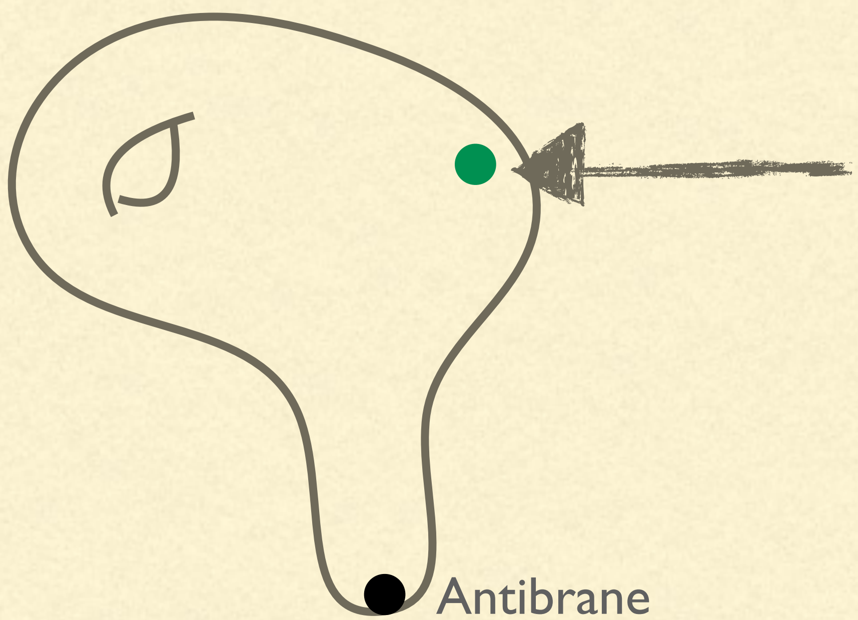

Suppose we add another stack of branes, with massless charged d.o.f

(for instance, a brane which doesn't confine)

then, it will violate FL

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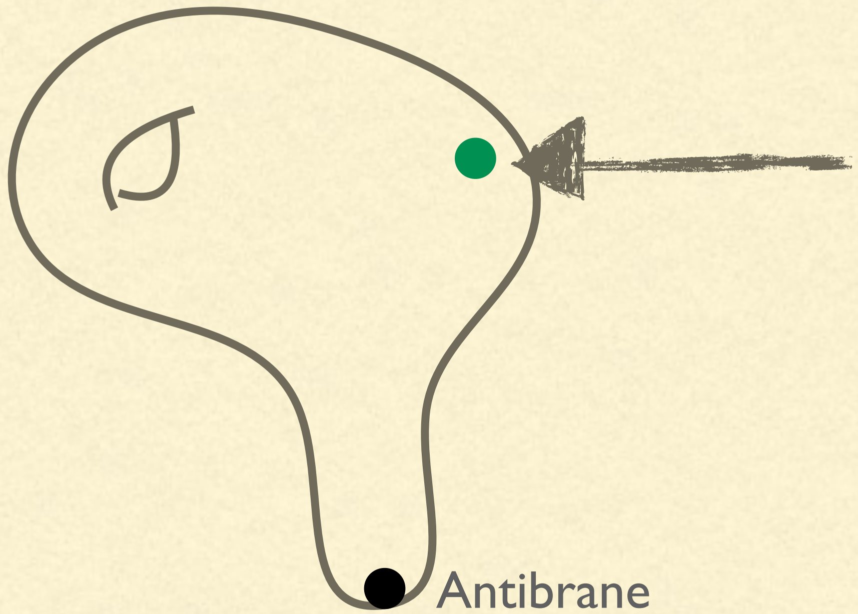

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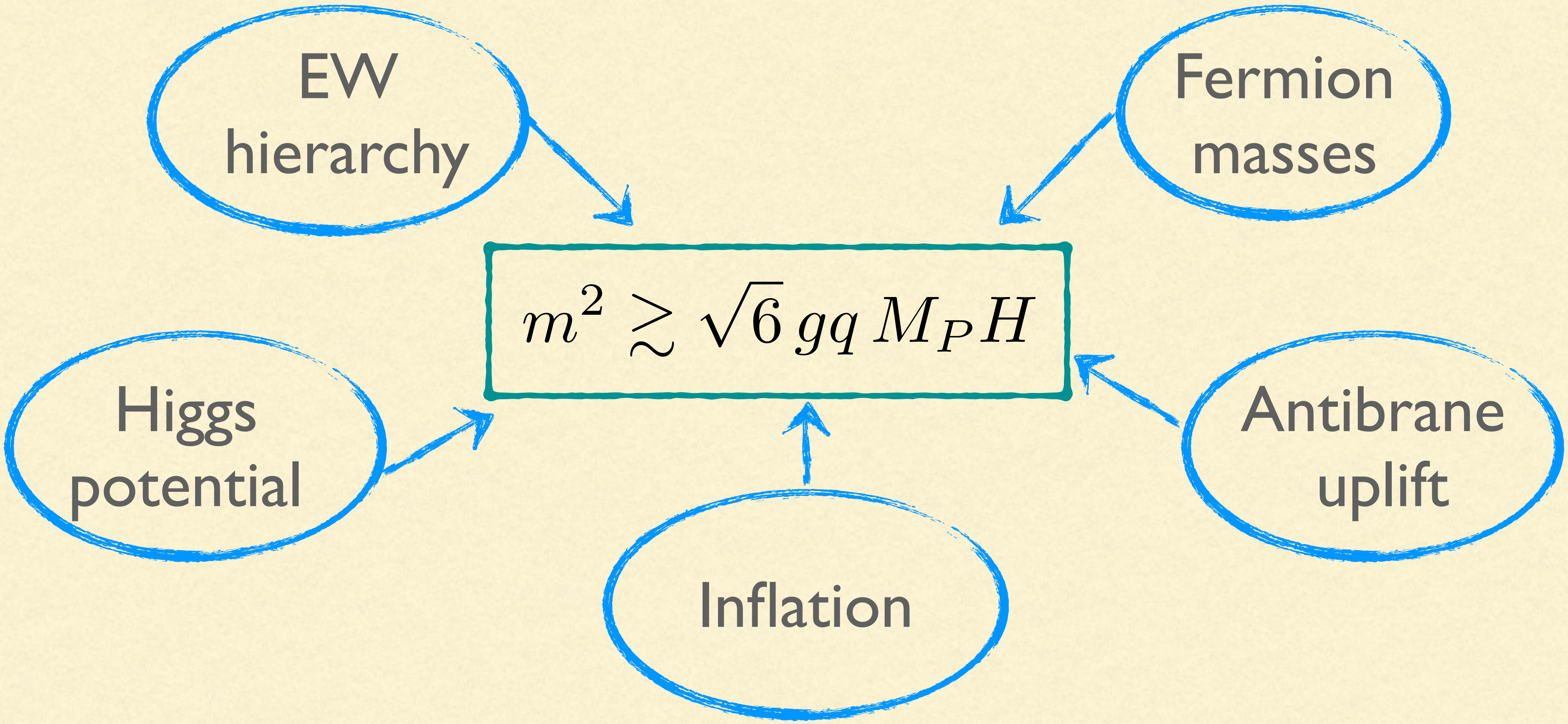
FL incorporates Swampland **intuition**: Stuff in the throat cannot fully **decouple**

TO WRAP UP



- Working out several of these connections
- Is it correct? More checks/arguments? Counterexamples?

Thank you very much!