The Cosmological Constant is probably zero

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Based on work with Francisco Pedro and Yang Liu 2303.17723 [hep-th]

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Take Home Message

In the Bousso-Polchinski set up, we can select the current vacuum on probabilistic grounds, provided we make some assumptions on the underlying parameters. Anthropics is not required.

This idea extends to a wide class of 4D EFTs containing families of four-form fields and dual scalars

The Cosmological Constant Problem

In standard QFT, vacuum energy density scales like M_{UV}^4

In GR, vacuum energy gravitates like a cosmological constant

Observed cosmological constant is many orders of magnitude less than the natural value

$$\Lambda_{\mathrm{obs}} \sim M_{pl}^2 H_0^2 \sim (\mathrm{meV})^4 \ll M_{UV}^4$$

How to solve/not solve the CC Problem

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Do you have a landscape?

How to solve/not solve the CC Problem

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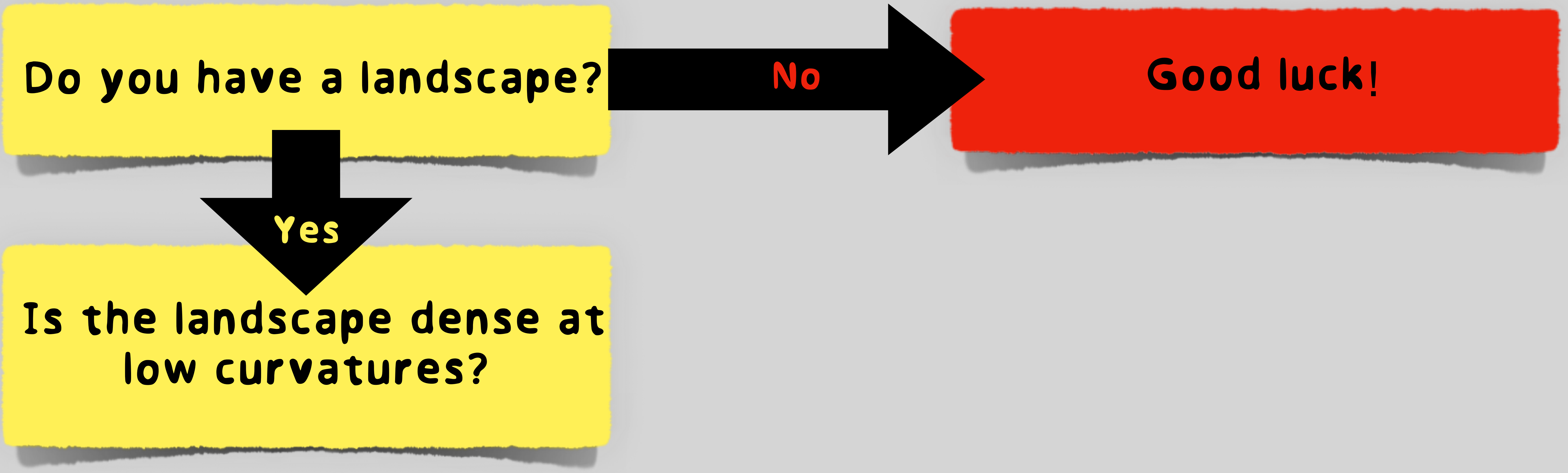

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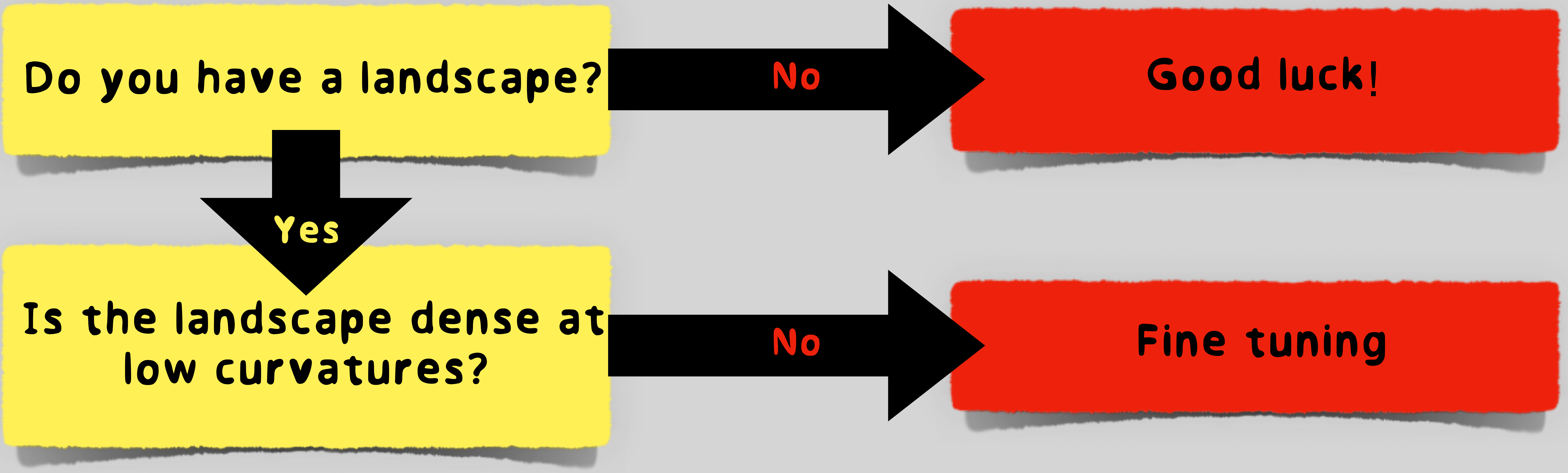

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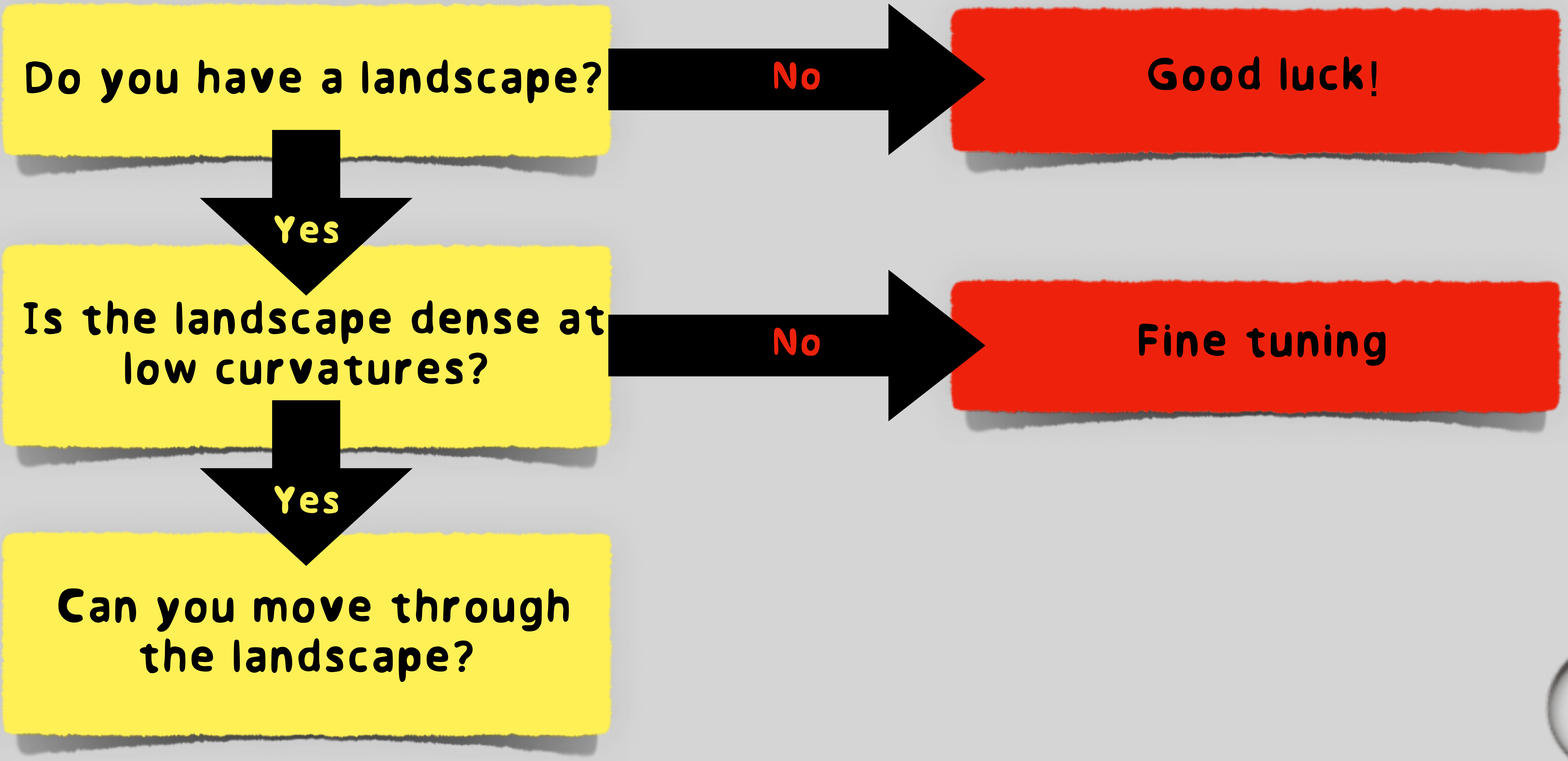

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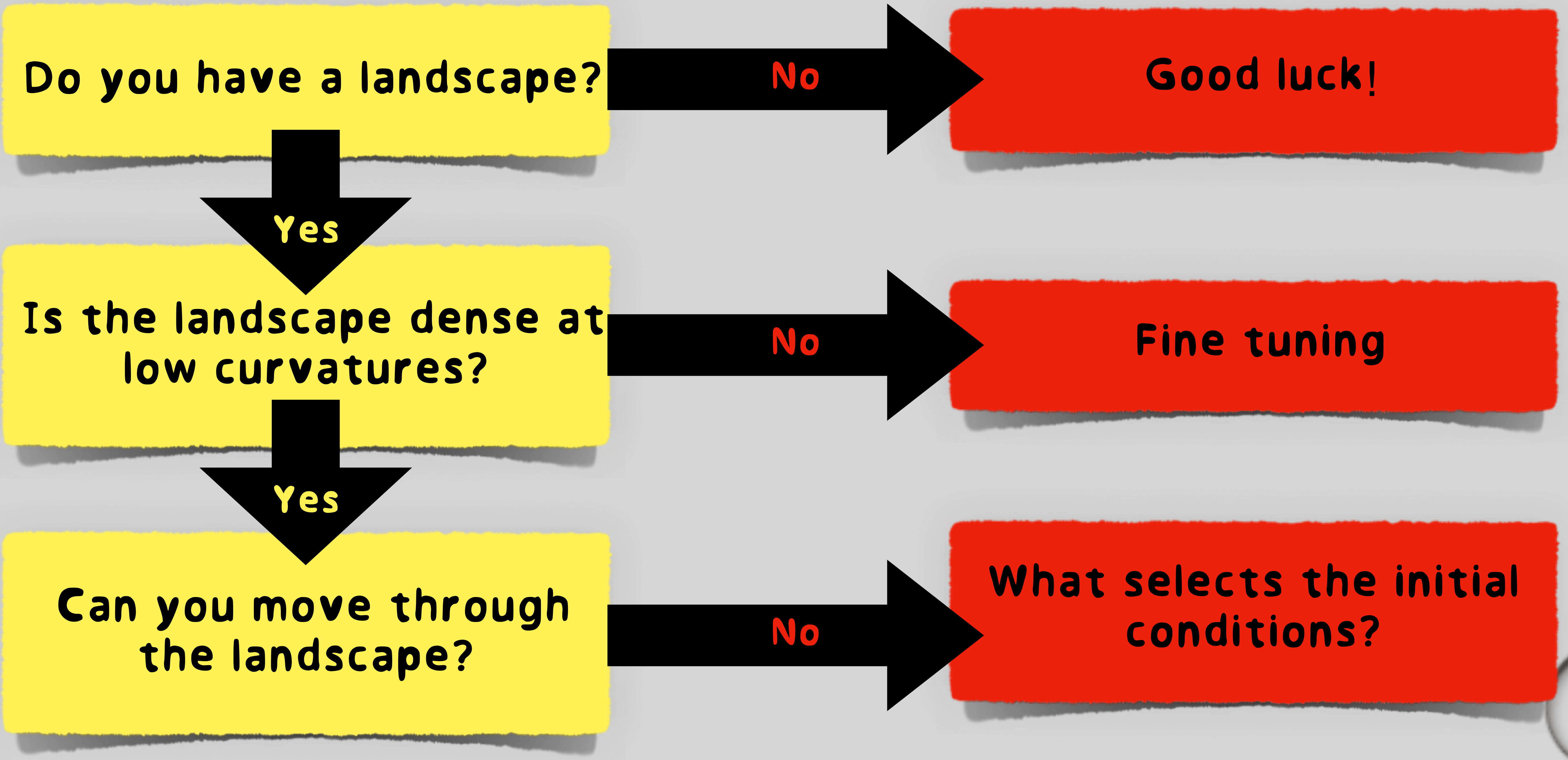

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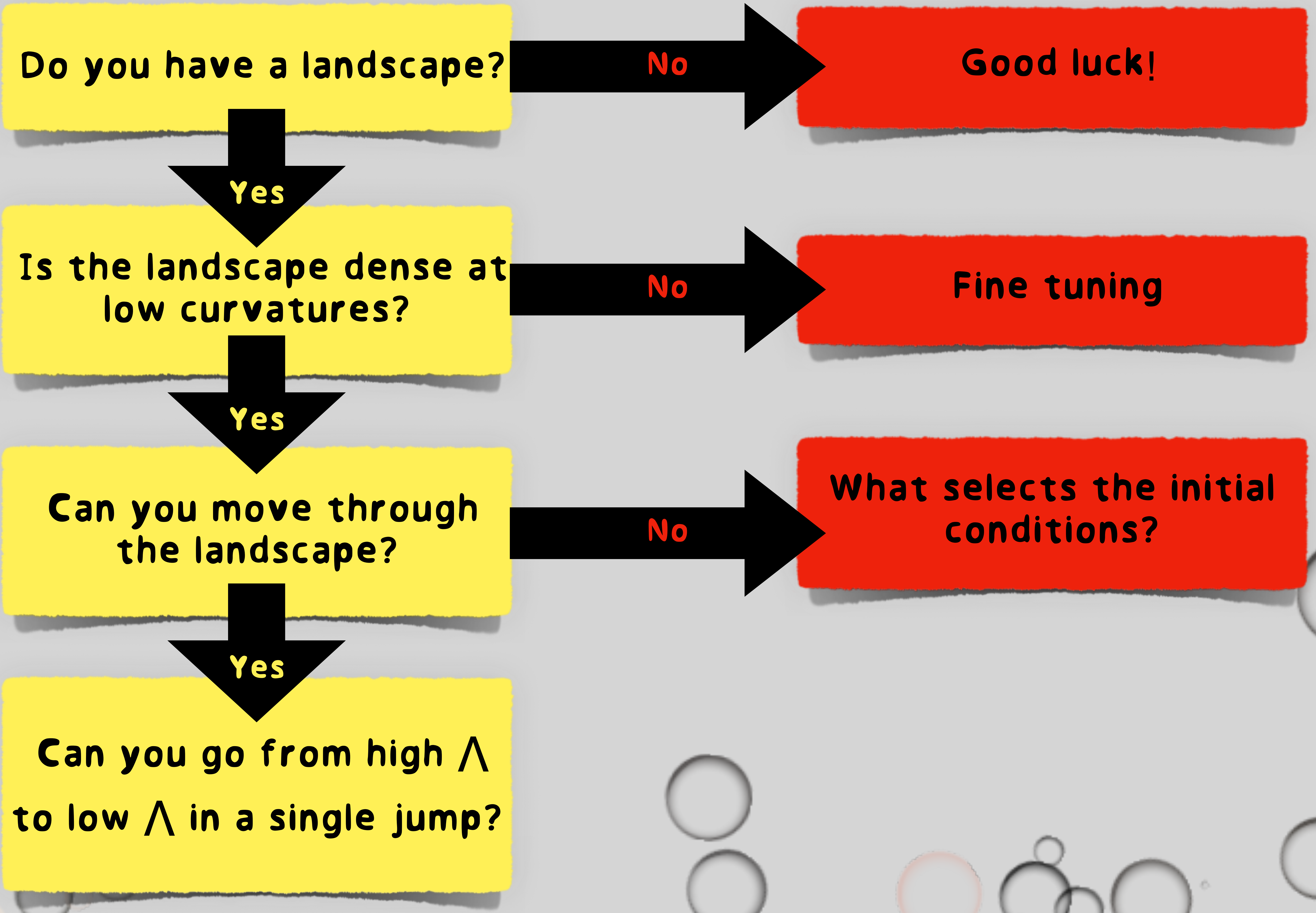

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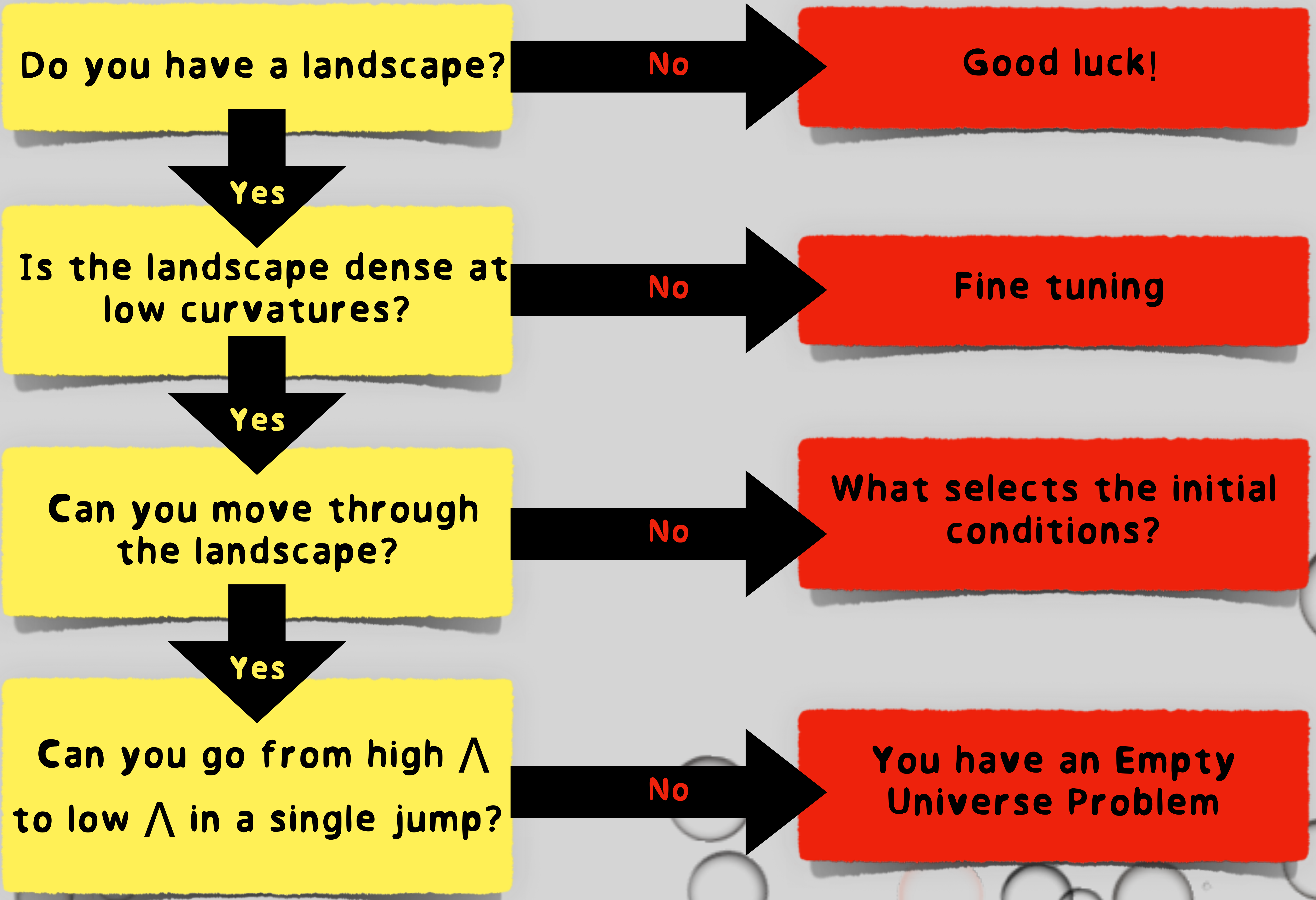

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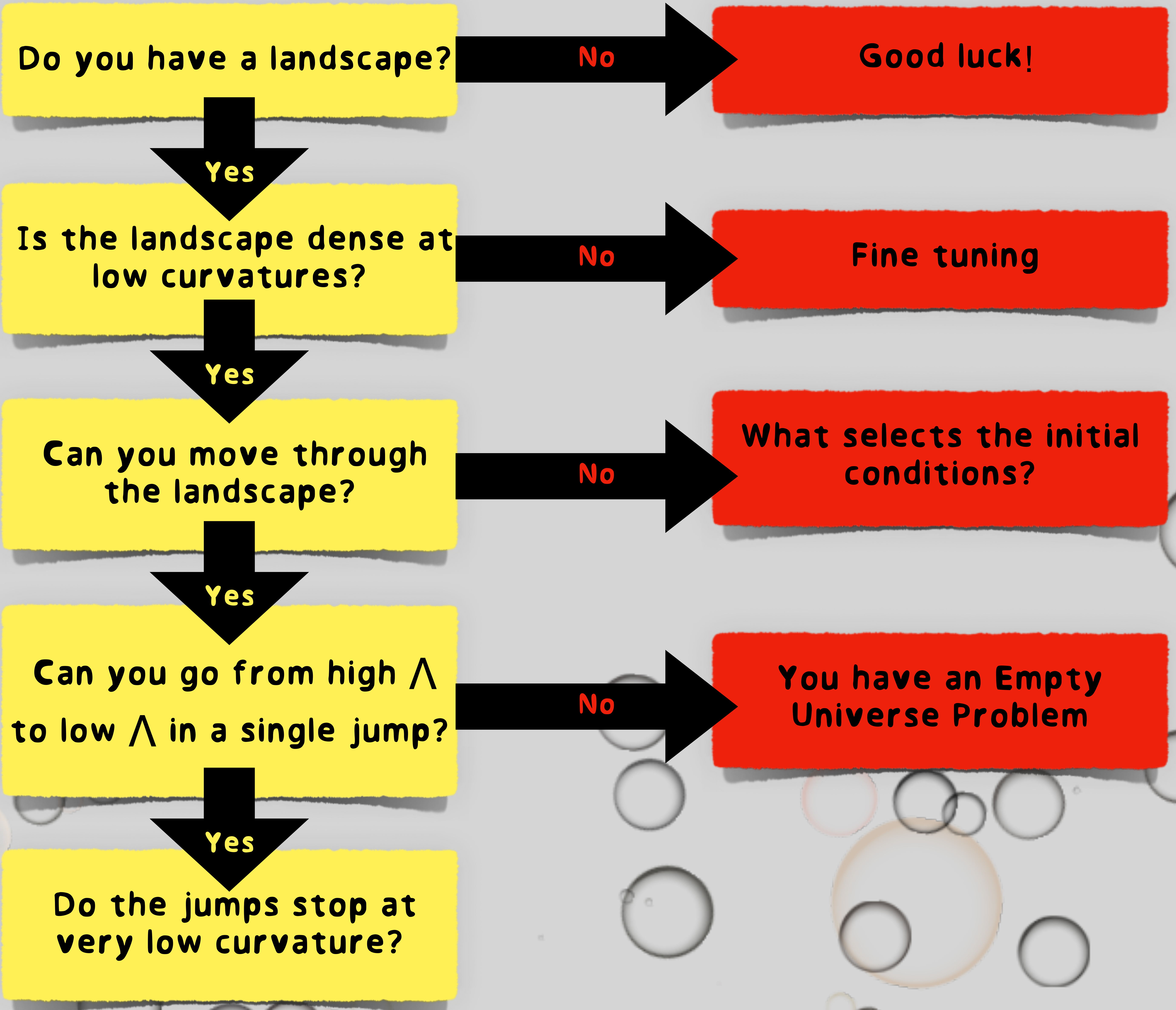

How to solve/not solve the CC Problem

Do you have a landspace? — No → Good luck!

Yes ↓

Is the landscape dense at low curvatures? — No → Fine tuning

Yes ↓

Can you move through the landscape? — No → What selects the initial conditions?

Yes ↓

Can you go from high Λ to low Λ in a single jump? — No → You have an Empty Universe Problem

Yes ↓

Do the jumps stop at very low curvature? — No → Use anthropics

How to solve/not solve the CC Problem

What if the answer to this

Do the jumps stop at very low curvature?

is yes?

How to solve/not solve the CC Problem

What if the answer to this **Do the jumps stop at very low curvature?** is yes?

PARTY TIME!

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$$\Lambda = 0$$

The Bousso-Polchinski set up

$$S = \int_{\text{bulk}} d^4x\sqrt{|g|}\,\frac{M_{pl}^2}{2}R + \sum_i \int_{\text{bulk}} -\frac{1}{2}F_i \wedge \star F_i - q_i \int_{\text{membrane}} A_i - \tau_i \int_{\text{membrane}} d^3\xi\sqrt{|\gamma|}$$

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three form field

A_i

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membrane charge

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four-form field strength

$$F_i = dA_i$$

three form field

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membrane charge

membrane tension

four-form field strength

$F_i = dA_i$

three form field

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Four forms are quantised in units of membrane charge

$$F^{(i)}_{\mu\nu\alpha\beta} = N_i q_i \epsilon_{\mu\nu\alpha\beta}$$

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Flux jumps by a single unit across a membrane

$$N_i \to N_i \pm 1$$

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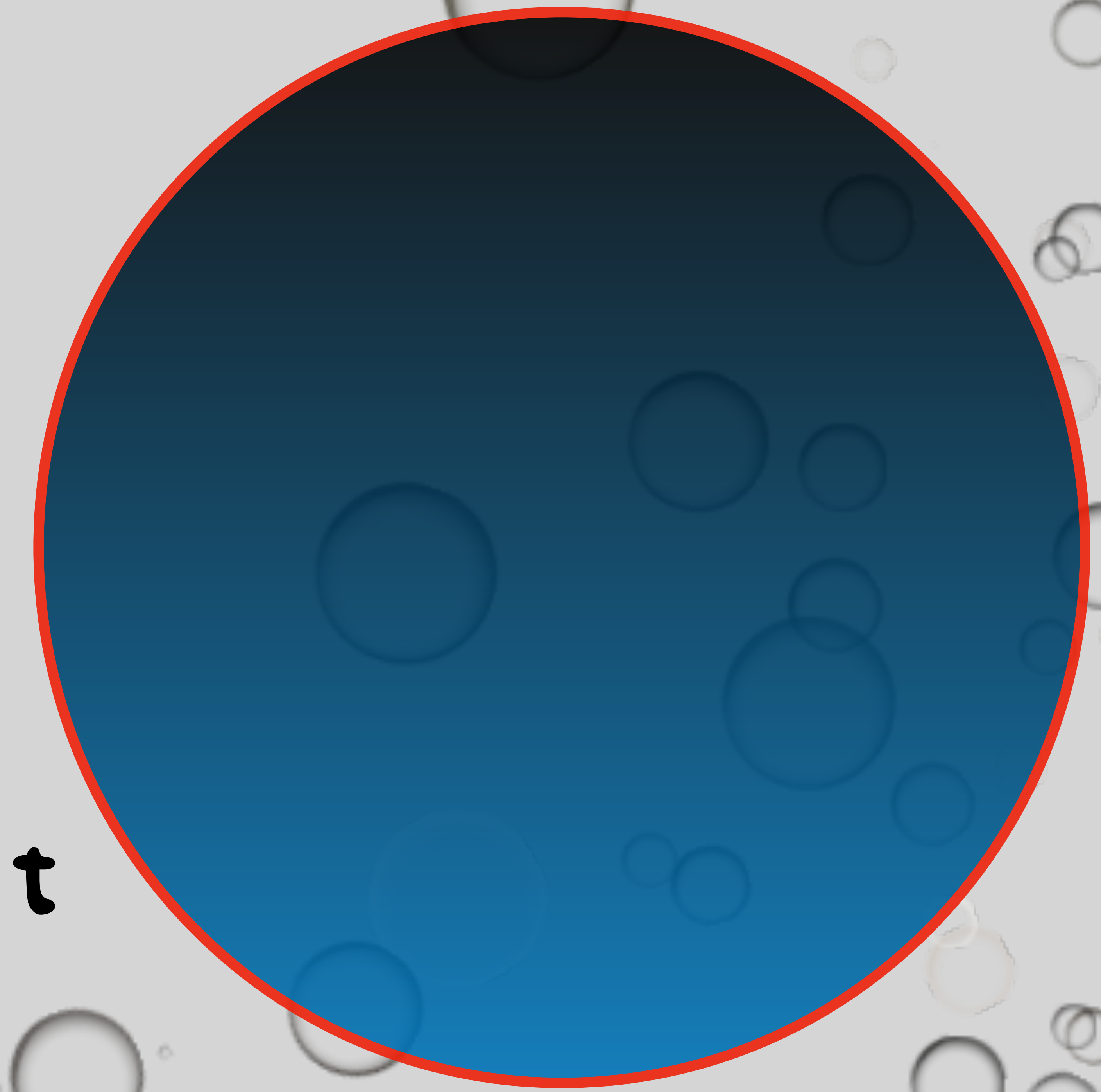

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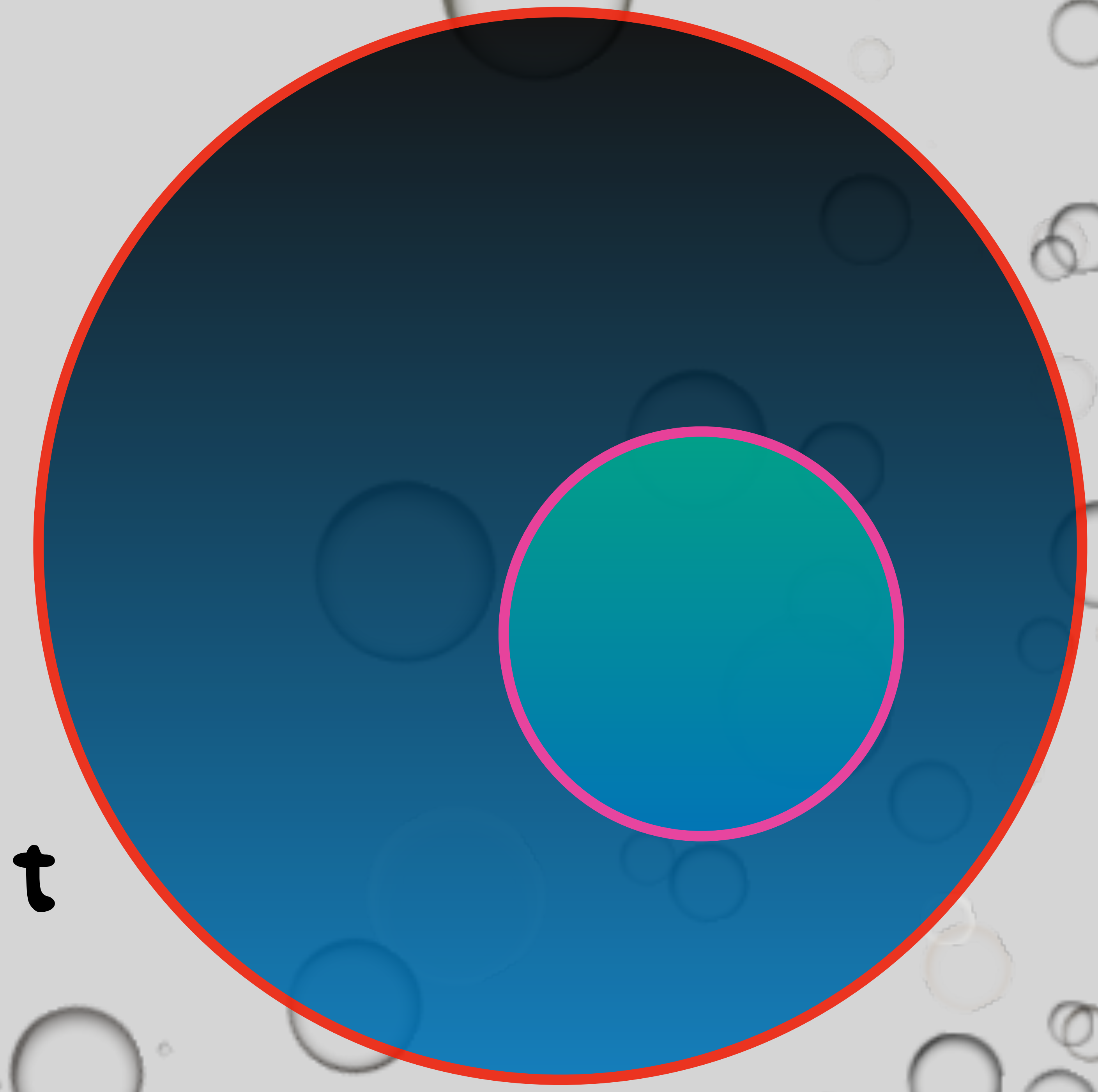

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The Bousso-Polchinski set up

Do you have a landscape?

Yes

Is the landscape dense at low curvatures?

Yes

Can you move through the landscape?

Yes

Can you go from high Λ to low Λ in a single jump?

Yes

Do the jumps stop at very low curvature?

Four-forms $F_{\mu\nu\alpha\beta} = 4\partial_{[\mu}A_{\nu\alpha\beta]}$

Bousso & Polchinski use O(100) four-forms

Membrane nucleation

Near Planckian membrane charge

Let's compute the membrane nucleation rate....

The Bousso-Polchinski set up

Membrane nucleation rate $\Gamma \propto e^{-B}$ where the bounce B has a potential pole as the parent vacuum approaches Minkowski

Specifically, as parent approaches Minkowski

$$B \sim \frac{6M_{pl}^4\Omega_3}{\Lambda_{\text{parent}}}(1-S) + \frac{8M_{pl}^6\Omega_3}{T^2X(X-1)^2}[(X-1)^2(1-S)+2S]$$

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Specifically, as parent approaches Minkowski,

$$B \sim \frac{12 M_{pl}^4 \Omega_3}{\Lambda_{\text{parent}}} \quad \text{if } X \lesssim \frac{2M_{pl}^2 q}{3T^2}\sqrt{8\,|V_{\text{QFT}}|} < 1$$

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There is a pole in the bounce as parent vacuum approaches MInkowski

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In the Bousso-Polchinski set up, we can select the current vacuum on probabilistic grounds, provided we make some assumptions on the underlying parameters. Anthropics is not required.

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