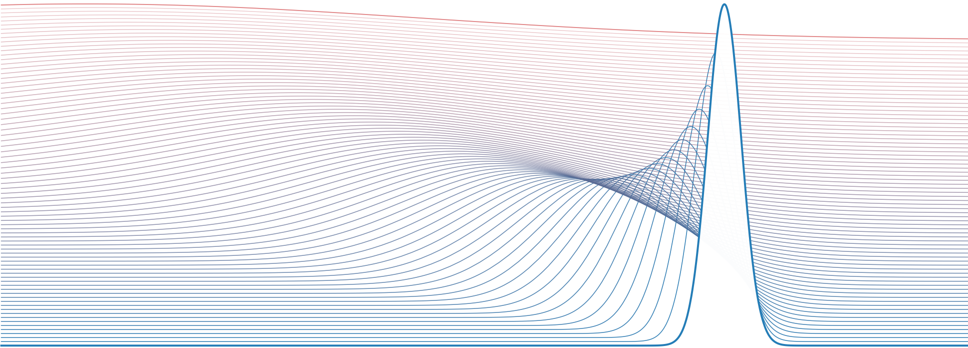
DECODING DIVERGENT DISTANCES



JOHN STOUT

HARVARD UNIVERSITY

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Motivation

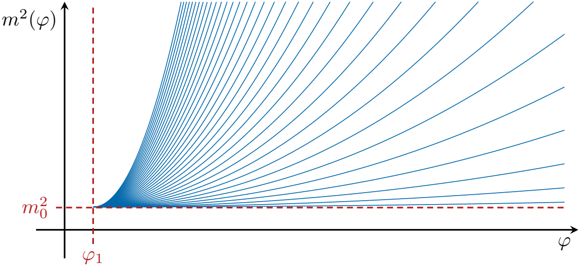
Why should the Swampland Distance Conjecture be true?

[Ooguri and Vafa '06]

$$m(\varphi_1) \sim m(\varphi_0) e^{-\lambda d(\varphi_1, \varphi_0)}, \qquad d \to \infty$$

Starting to have a good **top-down** understanding of it in special settings.

[Ooguri, Vafa, Grimm, Palti, Valuenzuela, Lee, Lerche, Wiegand, and many many others]



$d(\varphi_1, \varphi_0)$ measured using field space or Zamolodchikov metrics

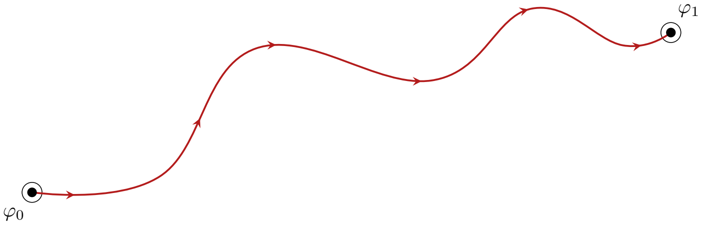
What's so special about infinite distance points?

Observation | Both the field space and Zamolodchikov metrics are proportional to the **quantum information metric**, so these **share** infinite distance points

[Provost and Vallee '80; Wootters '81; Miyaji et. al. '15, **JS** '21]

Defined for **arbitrary** families of theories, not just highly symmetric ones.

What do infinite distances mean? What do they need?



Bottom Line

Infinite distance limits are factorization limits, $\langle x^k \rangle \sim \langle x \rangle^k$

Unitarity dictates information metric has **universal** behavior

$$\mathrm{d}s^2 \propto \frac{\mathrm{d}\epsilon^2}{\epsilon^2}\,, \qquad \epsilon \to 0$$

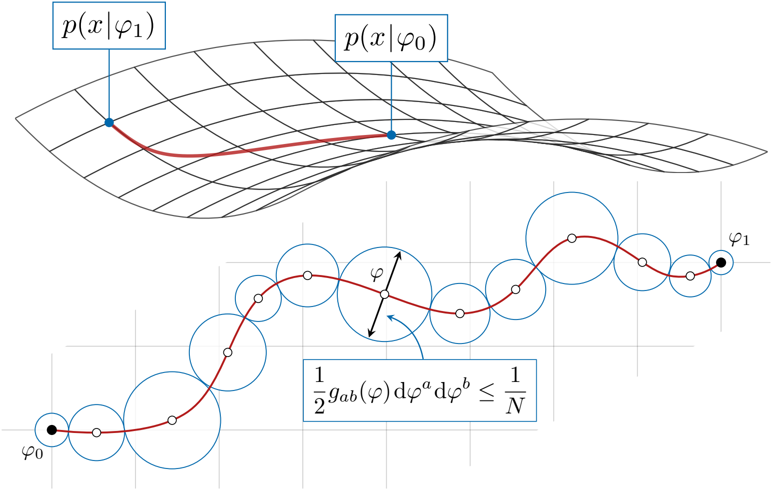
Explains why infinite distance points are weakly-coupled,
and provides a **bottom-up motivation for SDC**

Gravity obstructs factorization

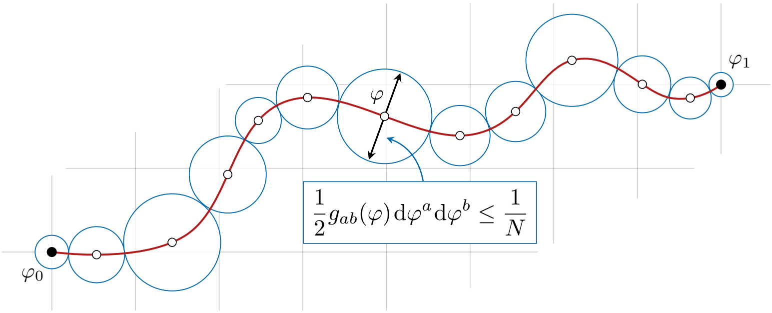
Towers of light fields "turn off" gravity, e.g. send $M_{\mathrm{pl}} \to \infty$,
so the theory can consistently realize these limits

[**JS** 2207.xxxxx]

A continuous family of theories $p(x|\varphi)$ forms a **statistical manifold**



The unique **information metric** $g_{ab}(\varphi)$ is defined by how readily we can distinguish $p(x|\varphi)$ from its neighbors with N samples



$$d_{\text{stat}}(\varphi_1, \varphi_0) = \int_0^1 \mathrm{d}t\,\sqrt{g_{ab}(t)\,\dot{\varphi}^a(t)\,\dot{\varphi}^b(t)} = \lim_{N\to\infty} \frac{N_{\text{dist}}(N)}{\sqrt{N/2}}$$

Information metric measures **statistical distance**, which **counts** number of distinguishable distributions along path in parameter space.

A theory is at infinite distance if it is **hyper-distinguishable**.

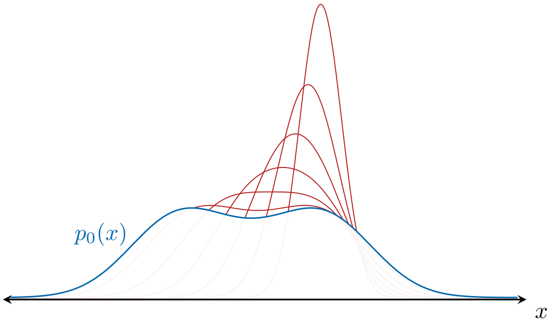
[**JS** '21]

Unitarity greatly restricts how $p(x\,|\,\epsilon)$ can behave as $\epsilon \to 0$.

These are probability distributions or quantum states

Families that approach a fixed distribution are at **finite distance**

$$p(x\,|\,\epsilon) \sim p_0(x) + \epsilon^\alpha p_1(x) + \cdots \to \mathrm{d}s^2 \propto \frac{\mathrm{d}\epsilon^2}{\epsilon^{2-2\alpha}}$$

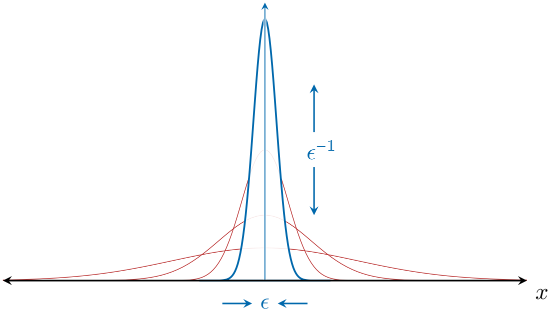


Critical points can be singular, $0 < \alpha < 1$, but **always** at finite distance

[JS 2207.xxxxx]

Infinite distance requires that the family **degenerates**

$$p(x\,|\,\epsilon) \sim \frac{1}{\epsilon}\eta(x/\epsilon) + \cdots \rightarrow \mathrm{d}s^2 \propto \frac{\mathrm{d}\epsilon^2}{\epsilon^2} + \cdots$$



Logarithmic singularity is **universal***

[*Assuming that expectation values remain finite as $\epsilon \to 0$]

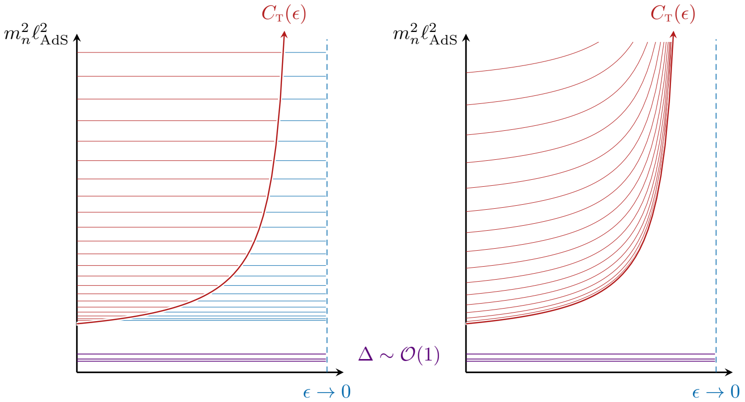
Infinite distance signals **factorization**, weak-coupling

See this **explicitly** for: massive fields, towers of fields, tensionless strings, classical limits, gauge theories, and generic large N limits

[**JS** 2207.xxxxx]

Gravity Abhors Factorization

$$\langle \mathcal{O}(x_1)\mathcal{O}(x_2)\mathcal{O}(x_3)\mathcal{O}(x_4)\rangle \supset \frac{\Delta^2}{C_{\rm T}} \frac{g_{\rm T}(u,v)}{x_{12}^{2\Delta} x_{34}^{2\Delta}} \neq \langle \mathcal{O}(x_1)\mathcal{O}(x_2)\rangle\langle \mathcal{O}(x_3)\mathcal{O}(x_4)\rangle + \cdots$$



Need to send $M_{\rm pl} \to \infty$ to **consistently** factorize correlation functions

$$\mathrm{d}s^2 \propto \mathrm{d}M_{\rm pl}^2/M_{\rm pl}^2 \to m_n(s) \sim m_n(0)\, \mathrm{e}^{-\lambda s}$$

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Thanks!

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