

The Higgs boson from a soft wall

with C. Csaki and S.J. Lee

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Motivation

Address SM Hierarchy Problem: mechanism to protect Higgs mass

$$\left(\frac{v}{\Lambda_{SM}}\right)^2 \begin{matrix} \nearrow \\ \searrow \end{matrix} \begin{matrix} \ll 1 \\ \gtrsim 1 \end{matrix}$$

- Naturalness
- Environmental Selection
- Finite Naturalness, ...
- Cosmological Relaxation
- ??

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Address SM Hierarchy Problem: mechanism to protect Higgs mass

$$\left(\frac{v}{\Lambda_{SM}}\right)^2 \begin{matrix} \nearrow \ll 1 \\ \searrow \sim 1 \end{matrix}$$

- Naturalness \implies new physics at the TeV
- Environmental Selection
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Address SM Hierarchy Problem: mechanism to protect Higgs mass

$$\left(\frac{v}{\Lambda_{SM}}\right)^2 \begin{matrix} \nearrow \ll 1 \\ \searrow \sim 1 \end{matrix}$$

- Naturalness \Rightarrow new physics at the TeV
- Environmental Selection $\left(\begin{matrix} \text{still room for new physics} \\ \text{Higgs sector is poorly constrained} \end{matrix} \right)$
- Finite Naturalness, ...
- Cosmological Relaxation
- ??

Introduction

approximate scale invariance



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free field theory

$$\Delta_{SM} = 1 + \mathcal{O}\left(\frac{\alpha}{4\pi}\right)$$

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Alternative possibility:

Higgs pole
(at a mass of 125 GeV)

+

Higgs continuum

- Bellazzini Csaki Hubisz Lee Serra Terning 1511.08218
- Unhiggs ...

Phenomenological Consequences

- Higgs form factors

- $gg \longrightarrow ZZ$

- $gg \longrightarrow HH$

- $h\bar{t}t$ coupling

A generic model

$$G(p^2) = -\frac{i}{(-p^2 + i\epsilon)^{2-\Delta}}$$

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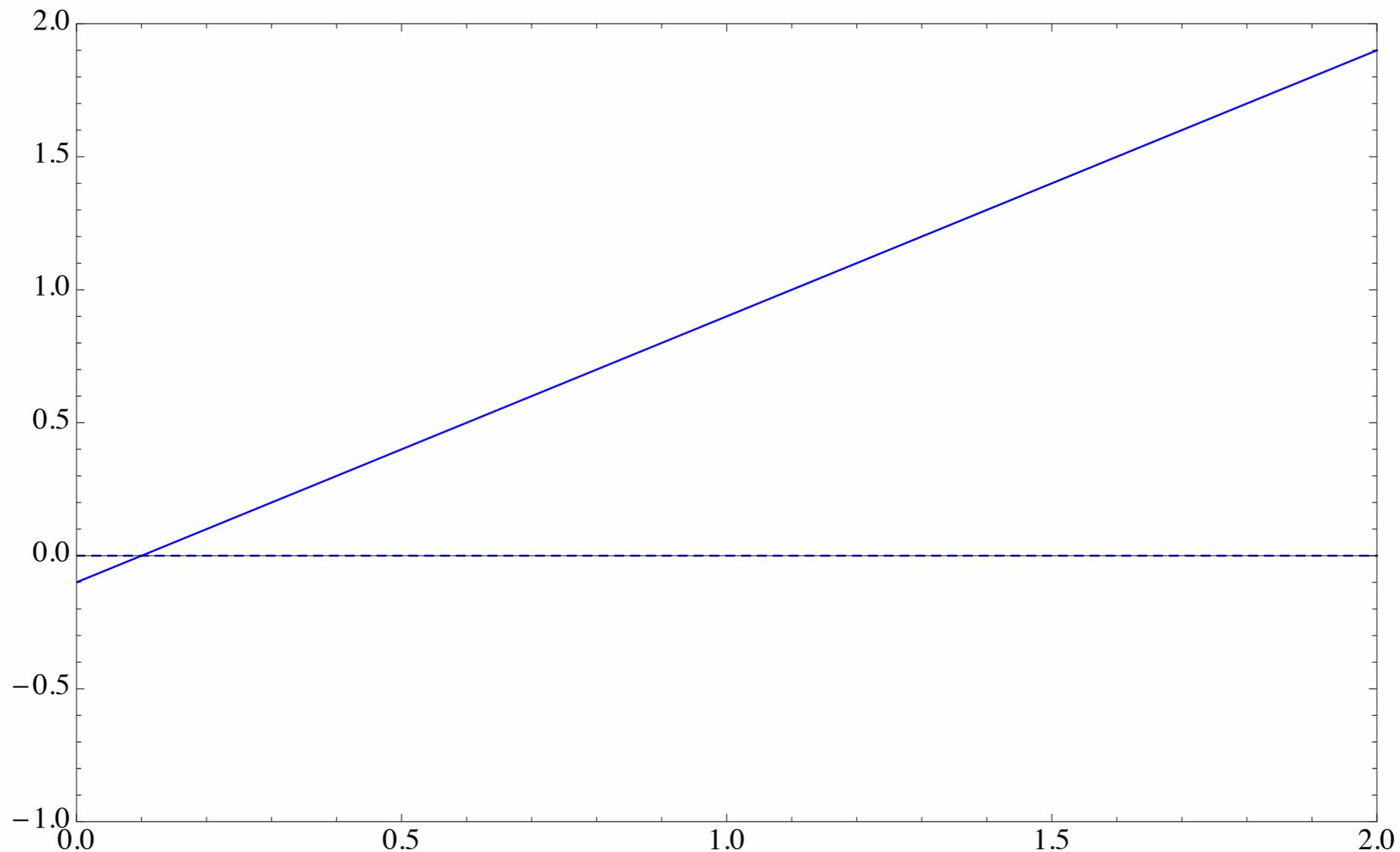
$$\mathcal{L} = -\frac{1}{2Z_h}h(\partial^2 + \mu^2)^{2-\Delta}h + \frac{1}{2Z_h}(\mu^2 - m_h^2)^{2-\Delta}h^2$$

$$G(p^2) = -\frac{iZ_h}{(\mu^2 - p^2 + i\epsilon)^{2-\Delta} - (\mu^2 - m_h^2)^{2-\Delta}}$$

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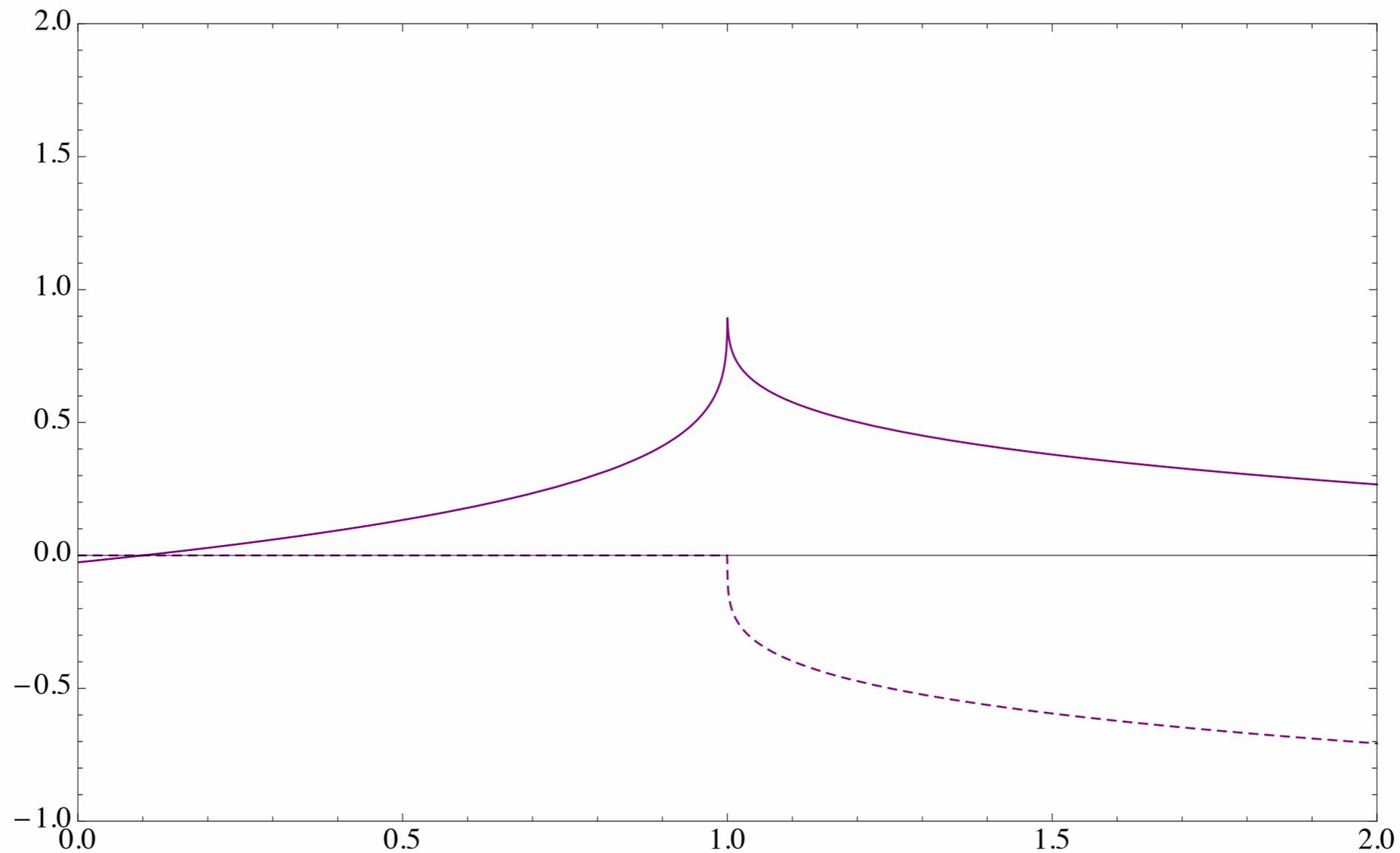
$$\Delta = 1$$



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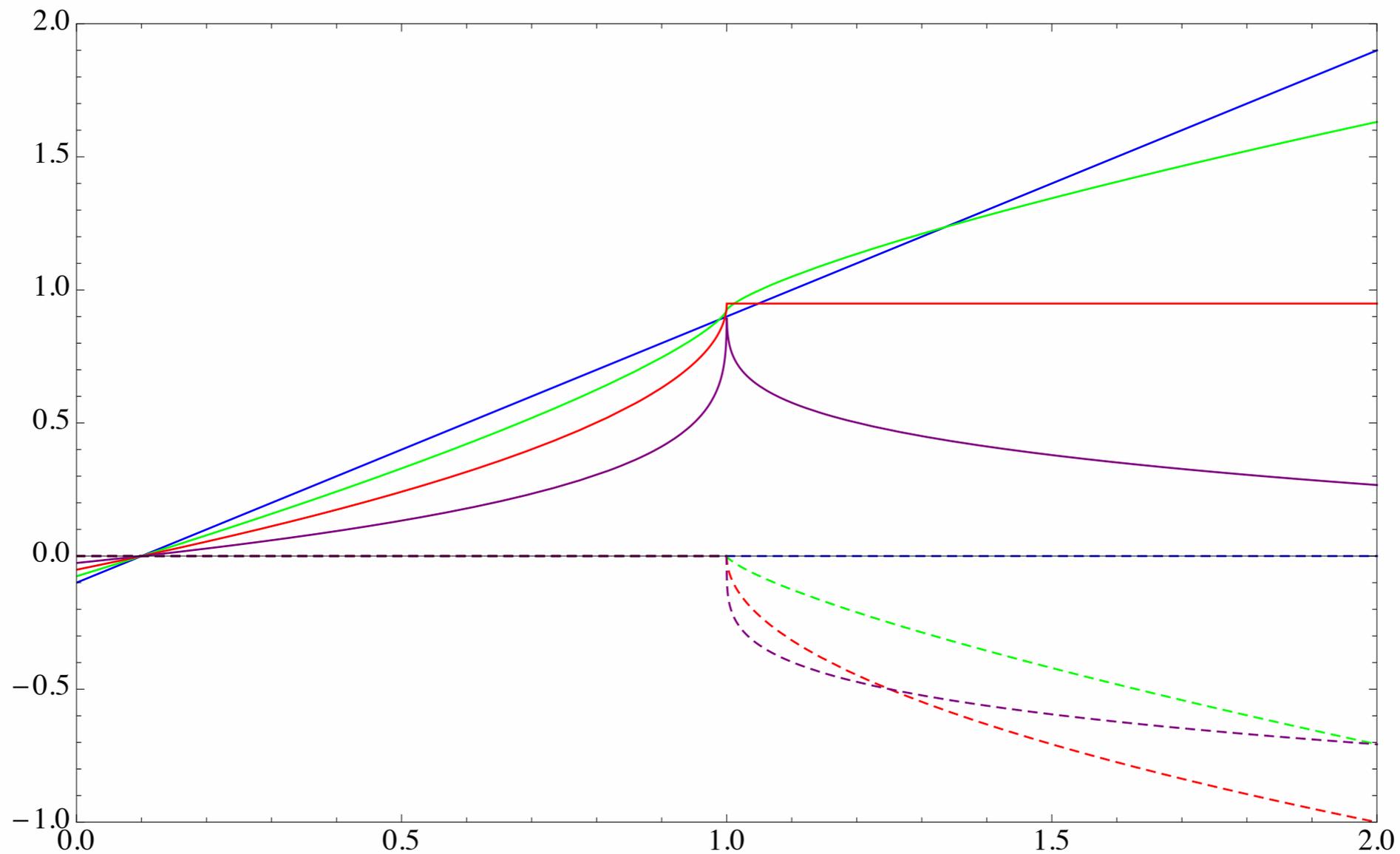
$$\Delta = 1.75$$



A generic model

$$G(p^2) = - \frac{iZ_h}{(\mu^2 - p^2 + i\epsilon)^{2-\Delta} - (\mu^2 - m_h^2)^{2-\Delta}}$$

$$\Delta = 1, 1.25, 1.5, 1.75$$



A 5D description: generalized free field theories

$$ds^2 = a(z)^2(dx^2 - dz^2)$$

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z dependent bulk mass:

$$\phi(z) = e^{\frac{4}{3}\mu(z-R)} \left(\frac{m^2 R^2 - 3\mu z}{R^2} \right)$$

$$G(p^2) \sim (\mu^2 - p^2)^{\Delta-2}$$

$$pR \ll 1, \mu R \ll 1$$

A new 5D model

$$ds^2 = a(z)^2(dx^2 - dz^2)$$

$$a_{UV}(z) = \frac{R}{z} e^{\frac{2}{3}(R-z)\mu_{UV}}, \quad a_{IR}(z) = \frac{R_p}{z} e^{\frac{2}{3}(R_p-z)\mu_{IR}}$$

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$$a(z)^{-4}(a(z)a''(z) - 2a'(z)^2) \leq 0$$

wec
holographic a-theorem

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bulk scalar:

$$\mathcal{L} = \sqrt{g} \left[\frac{1}{2} g^{MN} D_M \Phi^\dagger D_N \Phi - V(\Phi) - a(z)^{-1} \delta(z - R) V_{UV}(\Phi) - a(z)^{-1} \delta(z - z_\delta) V_{IR}(\Phi) \right]$$

A new 5D model

$$\hat{M}^2 = a^2 R \frac{\partial^2 V(\hat{v})}{\partial \hat{v}^2}$$

$$\hat{M}_{UV}^2 = a_{UV}^2 \phi_{UV}(z), \quad \text{and} \quad \phi_{UV}(z) = a_{UV}^{-2} \left(\frac{R}{z} \right)^2 \left(m^2 - \frac{3z\mu_{UV}}{R^2} \right),$$

$$\hat{M}_{IR}^2 = a_{IR}^2 \phi_{IR}(z), \quad \text{and} \quad \phi_{IR}(z) = a_{IR}^{-2} \left(\frac{R}{z} \right)^2 \left(m^2 - \frac{3z\mu_{IR}}{R^2} \right).$$

$$\nu^2 = 4 + m^2 R^2$$

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$$\Phi = R^{-1/2} \hat{v} + \hat{h}$$

$$\nu^2 = 4 + m^2 R^2$$

A new 5D model

$$\Psi = a^{3/2} \hat{h}$$

$$\left(-\partial_z^2 + \hat{V}\right) \Psi = p^2 \Psi$$

Falkowski, Perez-Victoria 0810.4940

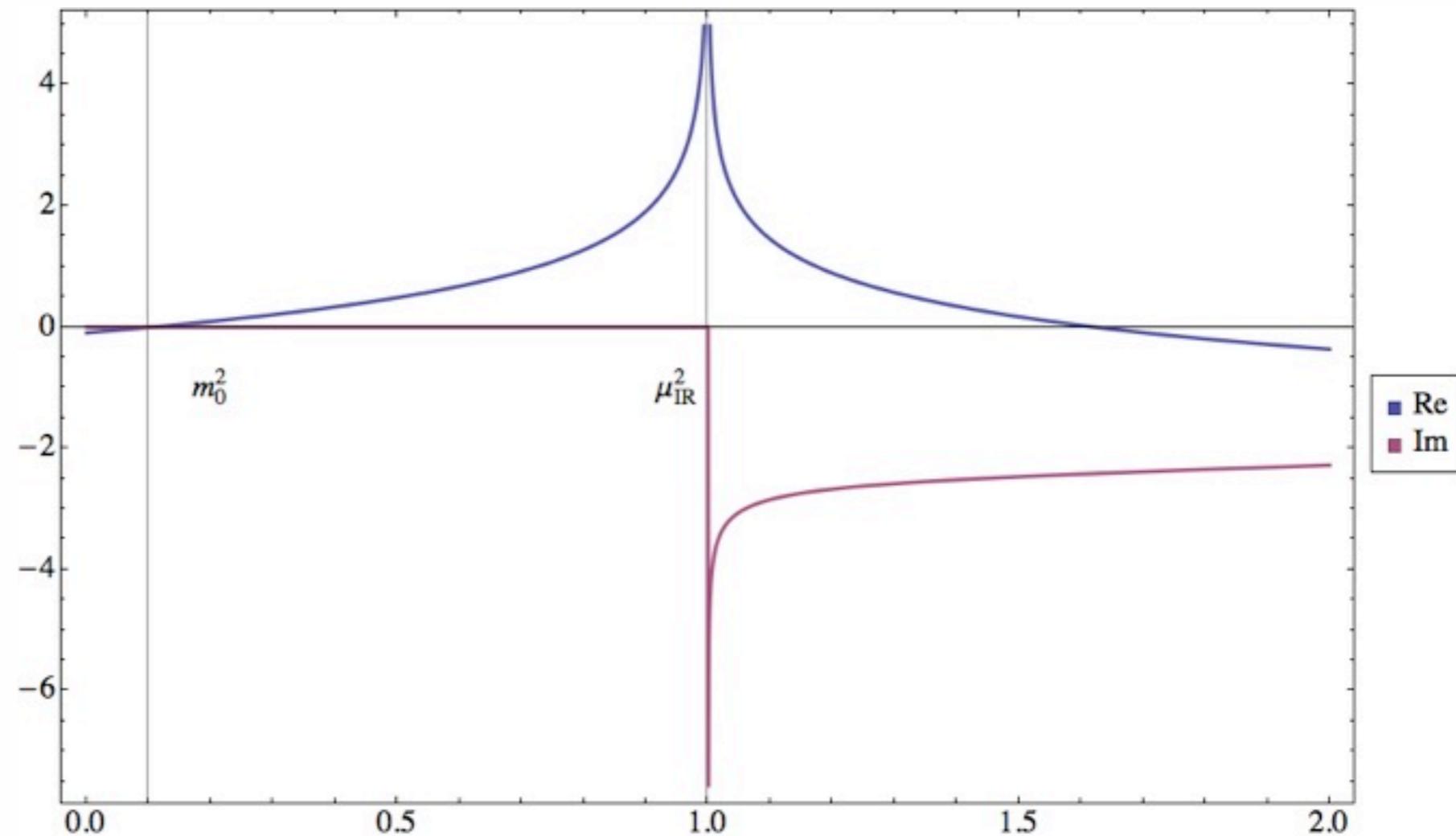
$$\begin{aligned} \hat{V} = & \frac{(4\nu^2 - 1 + 4\mu_{UV}^2 z^2)}{4z^2} \theta(z_\delta - z) + \\ & + \frac{(4\nu^2 - 1 + 4\mu_{IR}^2 z^2)}{4z^2} \theta(z - z_\delta) + \\ & + (\mu_{UV} - \mu_{IR}) \delta(z - z_\delta) \end{aligned}$$

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$$\left(-\partial_z^2 + \hat{V}\right) \Psi = p^2 \Psi$$

Falkowski, Perez-Victoria 0810.4940

$$S_{eff} = \frac{1}{2} \int \frac{d^4 p}{(2\pi)^4} h(-p) \hat{\Pi}(p^2) h(p)$$



Conclusions and Outlook

- Novel spectral properties
- Experimental consequences
- Extra dimensional construction
 - background geometry
 - potentially natural theory

Thank You