The Emergence Proposal with Multiple Moduli Fields

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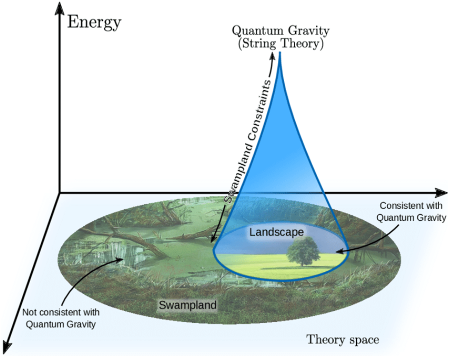
The Swampland Programme

Consistent set of conjectures motivated mainly (but not exclusively) by string theory (see e.g. Palti '19).



- No Global Symmetries Conjecture
- Distance Conjecture [Ooguri, Vafa '06]
- Weak Gravity Conjecture
- (A)dS Distance Conjecture
- Gravitino Conjecture

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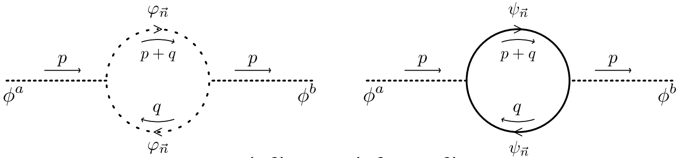
- The Emergence Proposal [Palti '19]
- The Emergent String Conjecture [Lee, Lerche, Weigand '18]

The Emergence Proposal

Emergence Proposal: *In a theory of Quantum Gravity all light particles in a perturbative regime have NO kinetic terms in the UV. These terms appear as an IR effect due to loop corrections induced by towers of light states (***strong***). Alternatively, the 1-loop kinetic terms are analogous to tree level ones (***weak***). [e.g. Castellano, Herraez, Ibañez '22]*

Comparison with usual renormalization procedure in QFT:



Integrating out light states with $m_{\vec{n}}(\phi^a) = m_{\vec{n}}(\phi_0^a + \delta\phi^a)$, where ϕ is a scalar (modulus) will produce a correction to the propagator matrix

$$D_{ab}(p^2) = \frac{1}{p^2 - \Pi_{ab}(p^2)}\,, \quad \Pi_{ab}(p^2) = \sum_{\vec{n}} \Pi_{ab,\vec{n}}(p^2)\,. \tag{1}$$

1-loop metrics arise similarly to the usual wavefunction renormalization

$$G_{ab}^{(1)} = \sum_{\vec{n}} \frac{\partial \Pi_{ab,\vec{n}}(p^2)}{\partial p^2}\bigg|_{p^2=0}\,. \tag{2}$$

The Species Scale

The cut-off of our theory is the **species scale**. For a $4D$ theory, that is [Dvali et al. '07]

$$\tilde{\Lambda} \sim \frac{M_{\rm pl}}{N_{\rm sp}^{1/2}}\,, \tag{3}$$

where $N_{\rm sp} = \begin{cases} \#\text{particles with } m < \tilde{\Lambda} & \text{(QFT picture)} \\ \text{S of minimum black holes} & \text{(BH picture)} \end{cases}$

Inconsistencies between the two derivations of $\tilde{\Lambda}$?

- Kaluza Klein towers ✓
- String tower:

QFT picture	BH picture
$\tilde{\Lambda}_{\rm QFT} \sim M_s \log(\frac{M_{\rm pl}}{M_s})$	$\tilde{\Lambda}_{\rm BH} \sim M_s$
$N_{\rm sp} = \frac{M_{\rm pl}^2}{M_s^2} \frac{1}{\log^2 \frac{M_{\rm pl}}{M_s}}$	$N_{\rm sp} = \left(\frac{M_{\rm pl}}{M_s}\right)^2$

Setup

Type IIA superstring compactified on a $\mathbb{Z}_2 \times \mathbb{Z}_2'$ orbifold of a 6-torus $T^6 = T^2 \times T^2 \times T^2$.

The mass of the **lightest states** in the **perturbative limit** ($\sigma \gg 1$) is

$$M^2 = \frac{M_{\rm pl}^2}{\sigma^2}\left\{ \sum_{I=1}^{3} \left[\left(\frac{m_1^I - v_I m_2^I + b_I n_1^I + b_I v_I n_2^I}{u_I^{\frac{1}{2}}}\, t_I^{\frac{1}{2}} \right)^2 + \left(\frac{(m_2^I - b_I n_2^I) u_I^{\frac{1}{2}}}{t_I^{\frac{1}{2}}} \right)^2 + \left(\frac{(n_1^I + v_I n_2^I) t_I^{\frac{1}{2}}}{u_I^{\frac{1}{2}}} \right)^2 + \left(n_2^I u_I^{\frac{1}{2}}\ t_I^{\frac{1}{2}} \right)^2 \right] + \kappa^2 N \right\}, \tag{4}$$

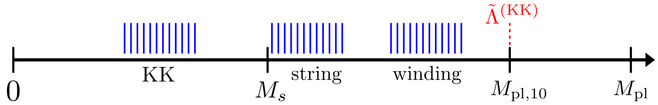
where $m_{1,2}^I$ are KK modes, $n_{1,2}^I$ are winding modes and N is the oscillator level.

Moduli content:

- 4D dilaton σ ($N = 2$ hypermultiplet)
- complex structure moduli v_I, u_I ($N = 2$ hypermultiplets)
- Kähler moduli t_I, b_I ($N = 2$ vector multiplets)

Including the superpartner of σ we have **14** real moduli in total!

The hierarchy we get is



Inclusion of only KK (and winding) modes is not enough. We need to include the **exponentially degenerate** string states.

The calculation is possible leading to

$$\frac{\tilde{\Lambda}}{M_s} \sim \frac{2\kappa}{\beta} \log(\sigma) \, , \tag{5}$$

while for the metrics

$$G^{(1)}_{\mathcal{M}_a\mathcal{M}_b} \simeq \frac{M_{\mathrm{pl}}^2}{2\,\mathcal{M}_a^2} \frac{1}{\log^2(\sigma)} \delta_{\mathcal{M}_a\mathcal{M}_b} \, , \quad \text{but} \quad G^{(1)}_{\sigma\sigma} \simeq \frac{M_{\mathrm{pl}}^2}{\sigma^2} \quad \text{and} \quad G^{(1)}_{\rho\rho} = 0 \, . \tag{6}$$

Results and Outlook

- The results **can** be made compatible with SUSY. (See e.g. Kiritsis, Kounnas '95)
- Our considerations were extended to the calculation of corrections to the gauge kinetic functions (again with multiplicative logarithm factors).
- The same pattern can be extended to the large t_1 and large u_1 limits, where the same pattern of **12 particle** and **1 tensionless string** contributions is exhibited. Bound states?

- Could the log's be completely unphysical?

- Where would the Emergence Proposal arise in a stringy calculation?

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Thank you for your attention!