Cecotti

Review of Swampland

I) finiteness conj.

- there is a uniform bound (in theory space)
  # massless spin s fields $\leq N_{\underbrace{d}_{\text{Spacetime dim.}}}(s)$

- clearly $N_d(>2)=0$, $N_d(2)=1$, $N_d(\frac{3}{2})=\frac{32}{2^{[\frac{d}{2}]}}$
  but also $N_d(0,\frac{1}{2},1)$?

II) no parameter

strong: couplings are vevs $\lambda = \langle \varphi \rangle$
weak: $\mathcal{L}_{eff}$ is rigid, i.e. $\nexists$ continuous parameters

- of course, if $\lambda = \langle \varphi_{heavy} \rangle$, where φ_{heavy} is in some UV-completion, then $\lambda \in \{$critical pts of $V(\varphi_{heavy})\}$ which is necessarily a set of isolated pts $\to$ if not, we would have light particles along valleys

- e.g. type IIB $\xrightarrow{\text{cpt.}}$ $M_4 \times \underbrace{CY3}_{\text{rigid}, h^{2,1}=0}$ — 1 vector graviphoton $\mathcal{N}=2$

$$\tau = \frac{\vartheta}{2\pi} + \frac{4\pi i}{g^2}$$

$\to \tau$ is not a generic thing, but determined as $\vartheta = \int_B \Omega / \int_A \Omega$, $g=$ something not understood, integrals of mod. forms

- of course, this comes from a heavy field of mass > cutoff

Rmk "Opposite" of naturalness. We claim thing is not consistent, unless very specially fine-tuned

III) no global symmetry

strong: consistent th. has no global symmetries (cont., disc., ...)

weak: $|G_g| < kd$

- of course $\mathcal{L}_{eff}$ may have emergent symmetries, exact up to cutoffs

- let G gauge gp, $H = G/G^0$ discr. gauge gp

IV) G_0 is cpt. $\underset{\text{Dirac}}{\Longrightarrow}$ $(e,m) \in \mathbb{Z}$

- essentially, we want integral fluxes

$$\Lambda = \bigoplus_{k=1}^{d} \Lambda_d \,, \quad d \neq 4,5+2$$

$$\Lambda = \Lambda_+ \oplus \Lambda_- \oplus \Big(\bigoplus_{n \neq d/2} \Lambda_n \Big) \quad d = 4,5+2$$

$$\begin{tikzcd} & H \arrow[dr, "f"] & \\ G \arrow[ur] \arrow[rr] & & \mathrm{Aut}\,\Lambda \end{tikzcd}$$

$f(H) \to$ U-duality gp

v) Completeness

Strong: every charge allowed by Dirac q. is realised

- black hole argument → if charges fall into BH, when it evaporates we get som

- now we come to the geometric conjectures
- $\mathcal{L}_{eff} = \cdots + \frac{1}{2}\sqrt{-g}\, G_{ij}(\varphi)\, \partial^\mu \varphi^i \partial_\mu \varphi^j + \cdots$
  $\Rightarrow \{\varphi^i\}$ chart on $\mathcal{M}$

Original conj:

$\dim \mathcal{M} \geq 1$. Then $\mathcal{M}$ complete, noncpt., finite-volume

- better: every subharmonic, bounded function on $\mathcal{M}$ is constant

Original: $\pi_1(\mathcal{M}) = 0$

- better: Let $\tilde{\mathcal{M}}$ fin. cover of $\mathcal{M}$. $\forall \varepsilon > 0$ $\forall [\gamma] \in H_1(\tilde{\mathcal{M}}, \mathbb{Z})$, we can find loop $\tilde{\gamma}$ s.t. $[\tilde{\gamma}] = [\gamma]$ and len $\tilde{\gamma} < \varepsilon$.