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A Strong Scalar Weak Gravity Conjecture and Some Implications

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We propose a new version of the scalar Weak Gravity Conjecture (WGC) which would apply to any scalar field coupled to quantum gravity. For a single scalar it is given by the differential constraint $(V'')^2 \leq (2V'''^2 - V''V'''')M_{\rm p}^2$, where V is the scalar potential. It corresponds to the statement that self-interactions of a scalar must be stronger than gravity for any value of the scalar field. We find that the solutions which saturate the bound correspond to towers of extremal states with mass $m^2(\phi) = m_0^2/((R/m)^2 + 1/(nR)^2)$, with $R^2 = e^{\phi}$, consistent with the emergence of an extra dimension at large or small R and the existence of extended objects (strings). These states act as WGC states for the scalar ϕ. It is also consistent with the distance swampland conjecture with a built-in duality symmetry. All of this is remarkable since neither extra dimensions nor string theory are put in the theory from the beginning, but they emerge. This is quite analogous to how the 11-th dimension appears in M-theory from towers of Type IIA solitonic $D0$-branes. From this constraint one can derive several swampland conjectures from a single principle. In particular one finds that an axion potential is only consistent if $f \leq M_{\rm p}$, recovering a result already conjectured from other arguments. The conjecture has far reaching consequences and applies to several interesting physical systems: i) Among chaotic inflation potentials only those asymptotically linear may survive. ii) If applied to the radion of the circle compactification of the Standard Model to 3D with Dirac neutrinos, the constraint implies that the 4D cosmological constant scale must be larger than the mass of the lightest neutrino, which must be in normal hierarchy. It also puts a constraint on the EW scale, potentially explaining the hierarchy problem. This recovers and improves results already obtained by applying the AdS swampland conjecture, but in a way which is independent from UV physics. iii) It also constraints simplest moduli fixing string models. The simplest KKLT model is compatible with the constraints but the latter may be relevant for some choices of parameters.

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