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Naturalness and the Weak Gravity Conjecture

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Content :

The weak gravity conjecture (WGC) is an ultraviolet consistency condition asserting that an Abelian force requires a state of charge q and mass m with q > m/mPl. We generalize the WGC to product gauge groups and study its tension with the naturalness principle for a charged scalar coupled to gravity. Reconciling naturalness with the WGC either requires a Higgs phase or a low cutoff at $\Lambda \sim q\, m_{Pl}$. If neither applies, one can construct simple models that forbid a natural electroweak scale and whose observation would rule out the naturalness principle.

Summary :

The weak gravity conjecture (WGC) asserts a powerful consistency condition on gauge theories coupled to quantum gravity: an Abelian, long-range force requires a state of charge q and mass m such that q>m/mPl. Failure of this condition implies the existence of stable black hole remnants and is in tension with no-hair theorems. In this paper, we argue that the WGC creates a non-perturbative obstruction to naturalness, which is the notion that dimensionless coefficients should take on O(1) values in the absence of enhanced symmetry. As an illustration, we show that for scalar quantum electrodynamics, a natural spectrum can actually be forbidden by the WGC, which bounds a radiatively unstable quantity, m, by a radiatively stable quantity, q. More generally, the WGC can be at odds with naturalness in any theory containing charged fundamental scalars. We extend the conditions of the WGC to more complicated theories with multiple gauge symmetries and particles. Finally, we discuss implications for the hierarchy problem and construct a simple model in which the natural value of the electroweak scale - at the cutoff - is forbidden by the WGC.

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