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Constraining Neutrino Masses, the Cosmological Constant and BSM Physics from the Weak Gravity Conjecture

Luis E. Ibáñez[1], Víctor Martín-Lozano[2], Irene Valenzuela[3,4]

[1]Departamento de Física Teórica and Instituto de Física Teórica UAM/CSIC, Universidad Autónoma de Madrid, Cantoblanco, 28049 Madrid, Spain

[2]Bethe Center for Theoretical Physics & Physikalisches Institut der Universität Bonn, Nußallee 12, 53115, Bonn, Germany

[3]Max Planck Institute for Physics, Föhringer Ring 6, 80805 Munich, Germany

[4]Institute for Theoretical Physics and Center for Extreme Matter and Emergent Phenomena Utrecht University, Leuvenland 4, 3584 CE Utrecht, The Netherlands

Abstract

It is known that there are AdS vacua obtained from compactifying the SM to 2 or 3 dimensions. The existence of such vacua depends on the value of neutrino masses through the Casimir effect. Using the Weak Gravity Conjecture, it has been recently argued by Ooguri and Vafa that such vacua are incompatible with the SM embedding into a consistent theory of quantum gravity. We study the limits obtained for both the cosmological constant Λ_4 and neutrino masses from the absence of such dangerous 3D and 2D SM AdS vacua. One interesting implication is that Λ_4 is bounded to be larger than a scale of order m_ν^4, as observed experimentally. Interestingly, this is the first argument implying a non-vanishing Λ_4 only on the basis of particle physics, with no cosmological input. Conversely, the observed Λ_4 implies strong constraints on neutrino masses in the SM and also for some BSM extensions including extra Weyl or Dirac spinors, gravitinos and axions. The upper bounds obtained for neutrino masses imply (for fixed neutrino Yukawa and Λ_4) the existence of upper bounds on the EW scale. In the case of massive Majorana neutrinos with a see-saw mechanism associated to a large scale $M \simeq 10^{10-14}$ GeV and $Y_{\nu_1} \simeq 10^{-3}$, one obtains that the EW scale cannot exceed $M_{EW} \lesssim 10^2 - 10^4$ GeV. From this point of view, the delicate fine-tuning required to get a small EW scale would be a mirage, since parameters yielding higher EW scales would be in the *swampland* and would not count as possible consistent theories. This would bring a new perspective into the issue of the EW hierarchy.