Observational consequences of charged Planck mass gravitini

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Max-Planck-Institut
Das Albert-Einstein-Institut
Quantengravitation
und Vereinheitlichte Theorien
Astrophysikalische

Golm 2022

Common papers

1. K.A. Meissner and H. Nicolai, *Conformal Symmetry and the Standard Model*, Phys.Lett. **B648** (2007) 312
2. K.A. Meissner and H. Nicolai, Phys. Lett. **B660** (2008) 260
3. K.A. Meissner and H. Nicolai, Eur.Phys.J. **C57** (2008) 493
4. K.A. Meissner and H. Nicolai, Acta Phys.Pol. **B40** (2009) 2737
5. K.A. Meissner and H. Nicolai, Phys.Rev. **D80**:086005 (2009)
6. A. Latosiński, K.A. Meissner and H. Nicolai, arXiv:1010.5417 [hep-ph]
7. A. Latosiński, K.A. Meissner and H. Nicolai, Nucl. Phys. **B868** (2013) 596-626
8. A. Latosiński, K.A. Meissner and H. Nicolai, Eur.Phys.J. **C73** (2013) 2336
9. K.A. Meissner and H. Nicolai, Phys. Lett **B718** (2013), 943
10. P. Dutta, K.A. Meissner and H. Nicolai, Phys. Rev. **D87** (2013) 105019
11. P.H. Chankowski, A. Lewandowski, K.A. Meissner and H. Nicolai, Mod. Phys. Lett. **A 30** No. 2 (2015) 1550006
12. K.A. Meissner and H. Nicolai, Phys. Rev. **D91** (2015) 065029
13. A.Latosiński, A. Lewandowski, K.A. Meissner and H. Nicolai, JHEP **1510** (2015) 170

Common papers

14. K.A. Meissner and H. Nicolai, Phys. Lett. **B772** (2017) 169
15. H. Godazgar, K.A. Meissner and H. Nicolai, JHEP **04** (2017) 165
16. K.A. Meissner and H. Nicolai, Phys.Rev. **D96** (2017) 041701
17. A. Lewandowski, K.A. Meissner and H. Nicolai, Phys. Rev. **D97** (2018) 035024.
18. K.A. Meissner and H. Nicolai, Foundations of Physics **48** (2018) 1150
19. G.F.R. Ellis, K.A. Meissner and H. Nicolai, Nature Physics **14** (2018) 770
20. K.A. Meissner, H. Nicolai and J. Plefka, Phys. Lett. **B791** (2019) 62
21. K.A. Meissner and H. Nicolai, *Standard Model Fermions and Infinite-Dimensional R-Symmetries*, Phys. Rev. Lett. **121** (2018) 091601
22. K.A. Meissner and H. Nicolai, *Planck Mass Charged Gravitino Dark Matter*, Phys.Rev. **D100** (2019) 035001
23. K.A. Meissner and H. Nicolai, *Superheavy Gravitinos and Ultra-High Energy Cosmic Rays* JCAP **09** (2019) 041
24. K.A. Meissner and H. Nicolai, *Supermassive gravitinos and giant primordial black holes*, Phys.Rev. **D102** (2020) 103008
25. K.A. Meissner and H. Nicolai, *Origin and growth of primordial black holes*, Phys.Lett. **B819** (2021) 136468

$N = 8$ supergravity

E. Cremmer, B. Julia, J.Scherk, B. de Wit, H. Nicolai,...

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  1 graviton
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  28 vectors
  56 spin 1/2 fermions
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- $N = 8$ supergravity field content:

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- we assume that there is some truth in it, at least in field content (maybe as some limit of M theory) even if we don't expect that it is realized at any scale

$N = 8$ SUGRA and the Standard Model

M. Gell-Mann, H. Nicolai, N.Warner

- after full susy breaking it has exactly 48 'massless' fermion dofs χ^{ijk} as in SM with 6 quarks and 6 leptons
  – possible explanation of 3 generations!

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- this correction is outside of $N = 8$ SUGRA!

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- The eight massive gravitini under $SU(3) \times U(1)_{em}$ as

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- strongly interacting gravitini ('gravimesons') should also be around us but in much lower abundance – UHECR

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- these DM gravitini, being charged and very heavy, have very distinctive features

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- Allowed window for masses: 40 orders of magnitude 10^{-12} eV...10^{28} eV

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- The other more promising are 'paleodetectors' – looking for ionizing tracks in old crystals
- signature should be very different from anything else known

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K.A.M. and H. Nicolai, JCAP 09 (2019) 041

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- But in the crust there are mostly iron nuclei – the products of the collisions should be light nuclei and not protons!
- extrapolating the formula for multiplicities from the LHC

$$\text{multiplicity} \sim 0.27\,\alpha_s(E)\exp\left(\frac{2.26}{\sqrt{\alpha_s(E)}}\right)$$

to E_P we get $\sim 10^6$ ($\Rightarrow$ particle energies 10^{21} eV)

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- we calculate the flux:
  - For strongly interacting particles the annihilation cross section σ varies only very slowly with the energy $\sqrt{s}$, and can be approximated by the non-perturbative (Froissart bound) formula

$$\langle\sigma\beta\rangle \sim \left[36 - 4\ln\left(\frac{\sqrt{s}}{\Lambda_{QCD}}\right) + 0.84\left(\ln\left(\frac{\sqrt{s}}{\Lambda_{QCD}}\right)\right)^2\right]\mathrm{mb}$$

with $\Lambda_{QCD} = 0.4$ GeV. For $\sqrt{s} = 2M_P$ we have $\langle\sigma\beta\rangle \sim 32\mathrm{mb}$

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- the relic abundance of color gravitini ρ_T at freeze-out

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$\Rightarrow$

$$\frac{m}{T} \sim 90 \quad \Rightarrow \quad \rho_T \sim 3\cdot 10^{59}\,\mathrm{m}^{-3}$$

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- the present day density of strongly interacting gravitini $\rho_T(a_T)/a_0)^3 \sim 10^{-9}$ m^{-3}

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- density of gravitini inside a neutron star

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- density of gravitini inside a neutron star

$$\rho_{NS} \sim 5 \cdot 10^9 \, \mathrm{m}^{-3}.$$

- The inverse lifetime of the strongly interacting gravitino as a function of the neutron star time from its birth is

$$\Gamma_{NS}(t) = \frac{\Gamma_{NS}(0)}{1 + \Gamma_{NS}(0)t}$$

with the initial value (and $\langle \sigma\beta \rangle \sim 32\mathrm{mb}$)

$$\Gamma_{NS}(0) \sim \left(5 \cdot 10^9\right) \cdot \left(32 \cdot 10^{-31}\right) \cdot \left(3 \cdot 10^8\right)\mathrm{s}^{-1} \sim 5 \cdot 10^{-12}\mathrm{s}^{-1}$$

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- we estimate the flux

$$N_E \sim \frac{10^{17} \cdot 10^{16}}{4(10^{24})^2}\ \mathrm{m}^{-2}\mathrm{s}^{-1}\ \sim\ 10^{-16}\ \mathrm{m}^{-2}\mathrm{s}^{-1}$$

which is close to the observed rate of one UHECR event per month and per 3000 km^2

Gravitini and giant black holes

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- (Color neutral) gravitini can form an initial black hole large enough to be colder than the surrounding and overcome Hawking evaporation
- Using the solution

$$\mathrm{d}s^2 = a(\eta)^2 \left[-(1 - 2m_{\mathrm{BH}}/r)\mathrm{d}\eta^2 + \frac{\mathrm{d}r^2}{1 - 2m_{\mathrm{BH}}/r} + r^2 \mathrm{d}\Omega^2 \right]$$

in the expanding Universe we get the bounds at $t \sim 100$ Myr

$$10^5 \ M_\odot \lesssim m_{\mathrm{BH}} \lesssim 2 \cdot 10^9 \ M_\odot$$

which is consistent with observations

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- such a gap in the mass distribution of black holes in the Universe would constitute indirect observational evidence for the existence of Hawking radiation.

Summary

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- time will tell...

Happy Birthday, Hermann!