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## Testing the photon and foundations of electromagnetism

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### Collaboration

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The Standard-Model Extension (SME) induces a mass to a photon [1,2], the only SM free massless particle. Observations of Fast Radio Bursts [3-5] and solar wind plasma [6,7] allowed estimates and limits listed in the Particle Data Group reviews. SME, classic (de Broglie-Proca and others) massive and non-linear electromagnetism theories (Born-Infeld, Heisenberg-Euler and others) determine a frequency shift of the photon in presence of a background, with which it exchanges energy [8]. This shift, added to expansion red shift, determines new cosmological scenarios, e.g., without recurring to the accelerated expansion to explain Supernovae data [9-11]. The upper limit of this shift would be  $7.7 \times 10^{-27}$  Delta f/f per metre which implies  $2.9 \times 10^{-18}$  in Delta f/f for an interferometer simulating the Earth-Moon distance. Finally, we apply the Heisenberg principle in the energy-time form to cosmological scales and read the Hubble constant as quantum measurement [12,13].

[1] 2017, Phys. Lett. B, 764, 203

[2] 2018, Eur. Phys. J. C, 78, 811

[3] 2016, Phys. Lett. B, 757, 548

[4] 2017, Phys. Lett. B, 768, 32

[5] 2017, Adv. Space Res., 59, 736

[6] 2016, Astropart. Phys., 82, 49

[7] 2022, arXiv:2205.02487 [hep-ph]

[8] 2019, Eur. Phys. J. C, 79, 590

[9] 2021, Eur. Phys. J. C, 81, 4

[10] 2022, Eur. Phys. J. Plus, 137, 253

[11] 2022, Eur. Phys. J. Plus, 137, 1386

[12] 2020, Found. Phys. 50, 893

[13] 2022, Found. Phys. 52, 23

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