On the Stability of Fundamental Couplings in the Galaxy

Pedro Vianez[1,2], Carlos Martins[1,3], Inês Mota[1,2], Simão João[1,2]

[1]Centro de Astrofísica, Universidade do Porto, Rua das Estrelas, 4150-762 Porto, Portugal
[2]Faculdade de Ciências, Universidade do Porto, Rua do Campo Alegre, 4150-007 Porto, Portugal
[3]Instituto de Astrofísica e Ciências do Espaço, CAUP, Rua das Estrelas, 4150-762 Porto, Portugal
pedromanuel.13@hotmail.com

Astrophysical tests of the stability of Nature's fundamental couplings are a key probe of the standard paradigms in fundamental physics and cosmology. In this report we discuss updated constraints on the stability of the fine-structure constant α and the proton-to-electron mass ratio $\mu = m_p/m_e$ within the Galaxy. We revisit and improve upon the analysis by Truppe *et al.* [1] by allowing for the possibility of simultaneous variations of both couplings and also by combining them with the recent measurements by Levshakov *et al.* [2]. By considering representative unification scenarios we find no evidence for variations of α at the 0.4 ppm level, and of μ at the 0.6 ppm level; if one uses the [2] bound on μ as a prior, the α bound is improved to 0.1 ppm. We also highlight how these measurements can constrain (and discriminate between) several fundamental physics paradigms.

Assumption	References	$\Delta\alpha/\alpha$ (10^{-7})	$\Delta\mu/\mu$ (10^{-7})
Other fixed	[1] only	*+0.32± 1.08*	*+0.68± 2.23*
Unification scenario	[1] + [16]	-0.04 ± 0.13	$+0.76 \pm 2.48$
Dilaton-type model	[1] + [17]	$+0.01 \pm 0.03$	$+0.66 \pm 2.18$
Atomic clocks	[1] + [18]	$+1.36 \pm 4.46$	-2.04 ± 6.69
Direct μ measurement	[1] + [2]	$+0.36 \pm 1.12$	*-0.03± 0.06*

Fig. 1. Comparison of the Constraints on variation of α and μ from the available data in [1] and [2], under several different assumptions. The inferred fractional variations are given with one-sigma uncertainties. Values in italics were obtained in the papers listed in the second collum; the others are the result of the present work.

[1] S. Truppe, R. J. Hendricks, S. K. Tokunaga, H. J. Lewandowski, M. G. Kozlov, C. Henkel, E. A. Hinds, and M. R. Tarbutt, Nature Communications **4**, 2600 (2013), 10.1038/ncomms3600, arXiv:1308.1496 [physics.atom-ph]
[2] S. A. Levshakov, D. Reimers, C. Henkel, B. Winkel, A. Mignano, M. Centurión, and P. Molaro, A. & A. **559**, A91 (2013), arXiv:1310.1850 [astro-ph.GA]
[16] A. Coc, N. J. Nunes, K. A. Olive, J.-P. Uzan, and E. Vangioni, Phys. Rev. **D76**, 023511 (2007), arXiv: astro-ph/0610733 [astro-ph].
[17] m. Nakashima, K. Ichikawa, R. Nagata, and J. Yokoyama, JCAP **1001**, 030 (2010), arXiv:0910.0742 [astro-ph.CO]
[18]M. C. Ferreira, M. D. Julião, C J. A. P. Martins, and A. M. R. V. L. Monteiro, Phys.Rev. **D86**, 125025 (2012), arXiv: 1212.4164 [hep-ph].