CONSISTENCY TESTS OF THE STABILITY OF FUNDAMENTAL COUPLINGS AND UNIFICATION SCENARIOS

M. C. FERREIRA,[1,2] O. FRIGOLA,[3] C. J. A. P. MARTINS,[1] A. M. R. V. L. MONTEIRO,[1,2] and J. SOLÀ[4]

[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] *Institut S'Agulla, Carretera de Malgrat 13, 17300 Blanes, Spain,*
[4] *Institut Manuel Blancafort, Avinguda 11 de Setembre 29, 08530 La Garriga, Spain.*

We summarize an exhaustive analysis [1] of current combined spectroscopic measurements of fundamental couplings, specifically the fine-structure constant α, the proton-to-electron mass ratio μ and the proton gyromagnetic ratio g_p. We also discuss some of the implications of the currently available measurements for fundamental physics, specifically for unification scenarios.

1 Introduction

The stability of nature's fundamental couplings is among the most profound open issues in astrophysics and fundamental physics, and has been identified by ESA and ESO as one of the key drivers for the next generation of ground and space-based facilities. At a phenomenological level, fundamental couplings *run* with energy and in many extensions of the standard model, particularly in theories with additional space-time dimensions, they also *roll* in time and *ramble* in space.

A detection of varying fundamental couplings will be revolutionary: it will prove that the Einstein Equivalence Principle is violated. However, improved null results are also important because they will tighten constraints on fundamental physics and cosmology.

Any Grand-Unified model predicts a relation between the variation of α and those of μ and other couplings, and therefore simultaneous measurements of both provide key consistency tests. The basic formalism for these tests was developed in reference 2 and 3.[2,3].

2 Phenomenological Models

We shall work on the assumption that varying fundamental couplings are due to a dynamical, dilaton-type scalar field (see [4,5,6,7] and references therein). We consider a class of grand unification models where the weak scale is determined by dimensional transmutation and the relative variation of all the Yukawa couplings is the same.

With these assumptions one finds that $\frac{\Delta\mu}{\mu} = [0.8R - 0.3(1+S)]\frac{\Delta\alpha}{\alpha}$ where R and S are phenomenological (model-dependent) parameters.

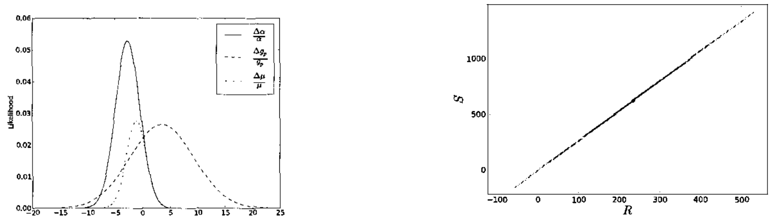

Figure 1 – Left panel: One-dimensional likelihoods for the relative variations of α, μ and g_p from the radio band dataset. Right panel: Constraints on the $R-S$ plane from the radio band dataset.

3 Consistency analyses and Constraints on Unification Scenarios

Different combinations of α, μ and g_p can be measured in the radio band. A joint analysis of this dataset can be done to find the most likely values of each one[1]. The left panel of Figure 1 shows the one-dimensional likelihood contours for each of these parameters. At 68.3% confidence level we find $\frac{\Delta\alpha}{\alpha} = -2.7 \pm 2.2$ ppm, $\frac{\Delta\mu}{\mu} = -1.1 \pm 1.8$ ppm and $\frac{\Delta g_p}{g_p} = 3.5 \pm 5.8$ ppm. In doing this we are neglecting a possible redshift dependence of the variations; more data would allow a more detailed analysis.

By using the phenomenological parametrizations introduced in Section 2, it is possible to translate the available measurements into constraints on the $R-S$ plane. As in previous analyses [4,5] there is a degeneracy direction,*i.e.*, these measurements constrain a particular combination of the parameters R and S. The right panel of Figure 1 shows the constraints in the R-S plane derived from the radio band set of measurements previously referred. At 68.3% confidence level we find $R = 237 \pm 86$ and $S = 630 \pm 230$.

4 Conclusions

We find no significant evidence for varying couplings. We also obtain constraints on the $R-S$ parameter space. Both results stem from radio band measurements of combinations of fundamental couplings.

Acknowledgments

We are grateful to Mariana Julião for useful discussions. This work was done in the context of the project PTDC/FIS/111725/2009 from FCT (Portugal). O.F. and J.S. acknowledge financial support from Programa *Joves i Ciència*, funded by Fundació Catalunya - La Pedrera. C.J.M. is also supported by an FCT Research Professorship, contract reference IF/00064/2012, funded by FCT/MCTES (Portugal) and POPH/FSE (EC).

References

1. M. C. Ferreira *et al*, *Phys. Rev.* D **89**, 083011 (2014).
2. A. Coc *et al*, *Phys. Rev.* D **76**, 023511 (2007).
3. F. Luo *et al*, *Phys. Rev.* D **84**, 096004 (2011).
4. M. C. Ferreira *et al*, *Phys. Rev.* D **86**, 125025 (2012).
5. M. C. Ferreira *et al*, *Phys. Lett.* B **724**, 1 (2013).
6. A. Avgoustidis *et al*, *JCAP* **1202**, 013 (2012).
7. A. Avgoustidis *et al*, arXiv:1305.7031.