Thermal leptogenesis in the type-I Dirac seesaw extension to the DFSZ axion model for dark matter

B.E. Castiblanco[1], **C. Quimbay** [1]

[1]*Departamento de Física, Universidad Nacional de Colombia, Bogotá, Colombia*

The type-I Dirac seesaw extension is made to the DFSZ axion model [1, 2], where light active neutrinos are Dirac particles and acquire mass through the canonical seesaw mechanism after the Peccei-Quinn and electroweak symmetry breaking, finding that the neutrino mass can be approximated to $m_\nu \approx v f_a/\Lambda_{UV}$ [3] in the (1+1)-scheme, result which relates the three energy scales involved in the model: the mass of the heavy sterile Dirac fermions (Λ_{UV}) introduced through the type-I Dirac seesaw extension, Peccei-Quinn spontaneous symmetry breaking scale given by the axion coupling constant (f_a), and the electroweak scale (v). As a consequence it is found that $10^3 f_a \sim \Lambda_{UV}$, hence neutrino Yukawa coupling associated to the QCD axion, which is candidate to dark matter [4], is highly supressed in comparison with the Yukawa coupling associated to the Higgs doublet, exactly by a factor which goes from 10^{-4} to 10^{-10}. Then, in the (3+3)-scheme it was found that the two Yukawa terms associated to the QCD axion and the Higgs doublet are linked together in a single Dirac neutrino effective mass matrix, whose nine components were computed explicitly and depend on active-sterile mixing parameters, introducing new sources for CP violation [5]. In addition, it is showed that if this Dirac neutrino effective mass matrix is hermitian, then the lepton mixing matrix U_{PMNS} is exactly unitary in this model. After this, the CP asymmetry factor is computed considering unflavoured thermal leptogenesis and the decay of a single heavy sterile Dirac fermion as the main contribution to the lepton asymmetry [6], finding a dependence on QCD axion decay constant f_a and active-sterile mixing parameters through the Dirac neutrino effective mass matrix, hence new sources of CP violation were found. Finally, it is found an expression for the baryon-antibaryon density $Y_{\Delta B}$ in terms of the CP asymmetry factor computed before [7]. The obtained results establish a robust theoretical framework that integrates neutrino physics, QCD axion, and cosmological parameters. Consequently, future measurements and experimental advancements in any of these domains hold the potential to yield valuable indirect information pertaining to the others.

For further details, consult the whole **research thesis** here.

[1] Zhitnitskij A. R., On possible suppression of the axion-hadron interactions. Yadernaya Fizika **31**, 2 (1980).

[2] Dine M, Fischler W, Srednicki M. A simple solution to the strong CP problem with a harmless axion. Physics letters B **104**(3), 199-202 (1981).

[3] Peinado, Eduardo, et al., Dirac neutrinos from Peccei–Quinn symmetry: A fresh look at the axion. Modern Physics Letters A. **35**, 21 (2020).

[4] Di Luzio L, Giannotti M, Nardi E, Visinelli L. The landscape of QCD axion models. Physics Reports **870**, 1-17 (2020).

[5] Mohapatra RN, Senjanović G. Neutrino masses and mixings in gauge models with spontaneous parity violation. Physical Review D **23**(1), 165 (1981).

[6] Zhi-zhong Xing, Flavor structures of charged fermions and massive neutrinos. Physics Reports. **854**, 1–147 (2020).

[7] Markus A Luty, Baryogenesis via leptogenesis. Physical Review D. **45**, 445 (1992).