DFSZ Axion in the CMB

The axion, being one of the most well motivated solutions to the strong CP problem (Peccei and Quinn, 1977), has been phenomenologically tested in several different contexts. Despite its extremely feeble interactions with the Standard Model (SM) particles, it could leave sizeable imprints on cosmological and astrophysical observables, providing a precious insight on its properties. Depending on the axion mass, a relativistic axion population can be thermally produced in the early universe. Such a population would act as warm dark matter, leaving imprints in the Cosmic Microwave Background (CMB). Observations and data of the CBM provide therefore constrains on the axion mass and couplings.

Unlike the KSVZ model, the axion couples at tree level to SM fermions in the DFSZ model. For this reason the DFSZ axion has been considered to explain the Xenon-1T excess (Aprile et al., 2020) and the Star cooling anomalies (Giannotti et al., 2017). In the recent paper by Ricardo Ferreira, Alessio Notari and Fabrizio Rompineve (Ferreira et al., 2020), the DFSZ axion has been analysed in light of the cosmological constraints coming from the CMB Planck 2018 data, BAO measurements, the SH_0ES 2019 measurement and the Pantheon supernovae dataset. More particularly, they determine the range of DFSZ axion masses and couplings compatible with the current observations.

For masses $m_a \gtrsim 0.1$ eV, the axion thermal population is produced through the axion-pion interactions at temperatures below the QCD phase transition ($T \lesssim 200$ MeV). Remarkably, considering the model dependent couplings of the DFSZ axion, it is found that axion production from leptons, while negligible for DFSZ-I model, it can be the dominant production channel in the DFSZ-II model assuming that the axion-pion coupling is suppressed. According to that, for a maximal axion-pion coupling $c_{a\pi} = 0.225$, they derive from the latest data sets a common bound to the type I and II models of $m_a \lesssim 0.2$ eV (95%CL), while in the pionphobic case $c_{a\pi} = 0.0225$ the bound on the axion mass is $m_a \lesssim 0.82$ eV (95%CL) in the DFSZ-I model (pion production) and $m_a \lesssim 0.61$ eV (95%CL) in the DFSZ-II (lepton production). Moreover, combining these cosmological data to the hints from astrophysics (Isern et al., 2018; Viaux et al., 2013) and the Xenon-1T anomaly through a Gaussian likelihood on the axion-electron coupling, they find that most of the parameter space suitable to explain (separately) the latter hints is in fact ruled out by cosmology, Fig.(1) (for a combined analysis ruling out the axion solution to *both* the stellar and Xenon observations see (Di Luzio et al., 2020)). In particular, for the Xenon-1T case, they restrict the axion mass to the range 0.07 eV $\lesssim m_a \lesssim 0.3$ eV for the DFSZ-II, while the bound in the DFSZ-I is $m_a \lesssim 1.8$ eV. For the stellar hint case, only the DFSZ-II model can be constrained since in the DFSZ-I scenario the thermal axion production is small in the stellar hint band. The bound is 3 meV $\lesssim m_a \lesssim 0.2$ eV. It is finally interesting to note that the Xenon-1T band can be probed by next generation CMB surveys in the DFSZ-I scenario (Fig.(1)).

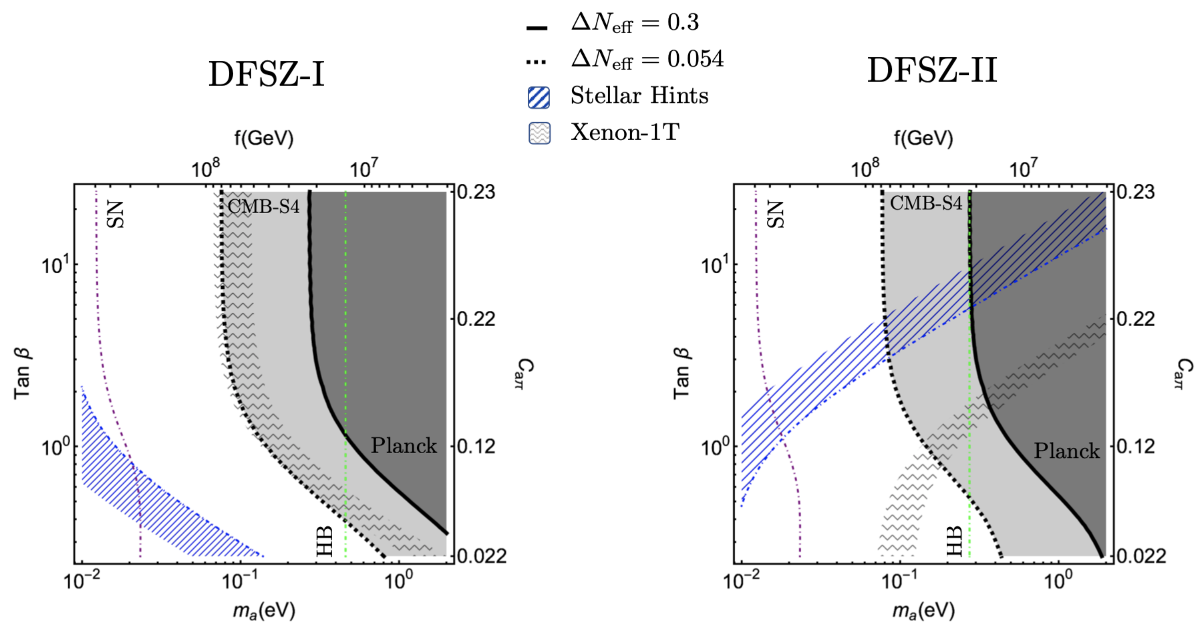

Figure 1: Parameter region compatible with Xenon-1T excess (curvy gray) and stellar hints (hatched blue) for the DFSZ-I (left) and DFSZ-II (right) axion. Regions where Δ Neff is large enough to be probed at 2σ by Planck18 and CMB-S4 are shaded in dark and light gray, respectively (Ferreira et al., 2020).

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