Polarized CMB Boltzmann hierarchy from νNSI

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Our goal?

$$\mathcal{L}_{\rm int} = h_{ij}\bar{\nu}_i\nu_j\phi + g_{ij}\bar{\nu}_i\gamma_5\nu_j\phi + \text{h.c.}$$

Neutrinos coupling to scalar and pseudo scalar particles.

Quantum Boltzmann Equation (QBE)

New cosmological signatures: CMB polarization

Light mediator limit

$$\frac{d}{d\eta}\Delta_P^+(\mathbf{K},k_c) + iK\mu\Delta_P^+(\mathbf{K},k_c) =$$
$$= -\tau'\left[-\Delta_P^+(\mathbf{K},k_c) + \frac{1}{2}\left(1-P_2(\mu)\right)\Pi(\mathbf{K})\right]$$
$$+ \frac{\left(g_{\phi\nu\nu}g_{\phi\gamma\gamma}\right)^2}{32\left(2\pi\right)^3}\frac{1}{a^2(\eta)}\left\{\Delta_P^+(\mathbf{K},k_c)\int_0^\infty dp_{1c}\,p_{1c}f_\nu^{(0)}(p_{1c})\int_{-1}^1 d\cos\alpha\,\mathcal{K}_l(k_c,p_{1c},\alpha)\right.$$
$$\left. + k_c\frac{\partial I_0(k_c)}{\partial k_c}\int dq_{2c}\,q_{2c}\left[\frac{\partial I_0(q_{2c})}{\partial q_{2c}}\right]^{-1}\int_{-1}^1 d\cos\theta\,\frac{(1-\cos\theta)\,\mathcal{F}(k_c,q_{2c},\theta)}{\sqrt{k_c^2+q_{2c}^2-2k_cq_{2c}\cos\theta}}\Delta_P^-(\mathbf{K},\mathbf{q}_{2c})\right\}$$

Heavy mediator limit

$$\frac{d}{d\eta}\Delta_P^+(\mathbf{K},k_c) + iK\mu\Delta_P^+(\mathbf{K},k_c) =$$
$$= -\tau'\left[-\Delta_P^+(\mathbf{K},k_c) + \frac{1}{2}\left(1-P_2(\mu)\right)\Pi(\mathbf{K})\right]$$
$$+ \frac{\left(g_{\phi\nu\nu}g_{\phi\gamma\gamma}\right)^2}{16\left(2\pi\right)^3}\frac{k_c^2}{M^4}\frac{1}{a^6(\eta)}\left\{\Delta_P^+(\mathbf{K},k_c)\int_0^\infty dp_{1c}\,p_{1c}f_\nu^{(0)}(p_{1c})\int_{-1}^1 d\cos\alpha\,\mathcal{K}_h(k_c,p_{1c},\alpha)\right.$$
$$\left. + k_c\frac{\partial I_0(k_c)}{\partial k_c}\int dq_{2c}\,q_{2c}^4\left[\frac{\partial I_0(q_{2c})}{\partial q_{2c}}\right]^{-1}\int_{-1}^1 d\cos\theta\,\frac{(1-\cos\theta)^3\,\mathcal{F}(k_c,q_{2c},\theta)}{\sqrt{k_c^2+q_{2c}^2-2k_cq_{2c}\cos\theta}}\Delta_P^-(\mathbf{K},\mathbf{q}_{2c})\right\}$$

Work done in collaboration with M. Lattanzi (INFN-FE), N. Bartolo (UniPD) and M. Zarei (IUT)

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