COSMOLOGICAL BOUNDS ON THREE SCENARIOS OF AXION-LIKE PARTICLES AND CONDENSATES FROM NON-EQUILIBRIUM QFT

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Based on work in progress with R. Passante & L. Rizzuto

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GOALS AND AN OUTLINE

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From the quantum EoMs of φ and Δ_ϕ, along with the help of the Liouville-Von Neumann equation, we get the following fully relativistic coupled Boltzmann equations:

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Objective: Get the relic abundances and ΔN_{eff} ($\varphi = \varphi(t)$).

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BOLTZMANN TRANSPORT EQUATIONS OF ALPS AND CONDENSATES

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- We get for each model i the following Boltzmann equations:

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- We are solving them numerically by MicrOMEGAs.

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(this last is the same result obtained in the recent preprint Jain, M., Maggi, A., Ai, W. Y., & Marsh, D. J. (2024) [4])

SUMMARY AND CONCLUSIONS

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1. We have developed a full formalism for studying the evolution equation of the ALP distribution function, for both the "particle" and the "condensate" components.

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4. Adopt our formalism to study the distribution function of the topological defects of QCD axion and use it as an alternative method to (numerically) evaluate the axion spectrum and its spectral index q.

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Thanks
for your attention!

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ADDITIONAL SLIDES

SECOND CASE: PHOTOPHOBIC ALPS

$$\Gamma_{2PI}[\psi,\Delta_\phi,\Delta_\gamma] = S[\psi] + i/2\,\mathrm{Tr}\ln\Delta_\phi^{-1} + i/2\,\mathrm{Tr}\ln\Delta_f^{-1} + i/2\,\mathrm{Tr}[G_\phi^{-1}\Delta_\phi] + i/2\,\mathrm{Tr}[G_f^{-1}\Delta_f] \tag{1}$$

where we have explicitly

$$\Delta_{f,mn} = \langle\bar{\Psi}_m(x)\Psi_n(y)\rangle \tag{2}$$

$$G^{ab,-1}_{f,mn} = ic^{ab}(i\gamma^\mu\partial_\mu - m_f - g_{aff}\partial_\mu\psi\gamma^\mu\gamma_5) \tag{3}$$

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QUANTUM EOMS

Precisely, we get from both the two methods the following quantum EoMs for $\varphi(x) = \langle\phi\rangle$ and $\Delta_\phi(x,y) = \langle T\phi(x)\phi(y)\rangle$:

$$-(\Box + \tilde{m}_\phi^2)\Delta^{ab}(x_1,x_2) - \sum_c c\int d^4x_3 \Pi_\phi^{ac}(x_1,x_3)\Delta^{cb}(x_3,x_2) = ic^{ab}\delta(x_1-x_2) \quad (4)$$

$$(\Box + \tilde{m}_\phi^2)\varphi + \frac{\lambda_\phi}{2}\Delta_\phi^{++}(x,x)\psi - \frac{\delta\Gamma_2}{\delta\phi^+}|_{\phi^+=\phi^-=\psi} + g_\chi \Delta_{\chi,\tilde{F}F} = 0 \quad (5)$$

With both methods, we assume the SM particles in our models are at thermal equilibrium.

EXAMPLE OF Γ_2

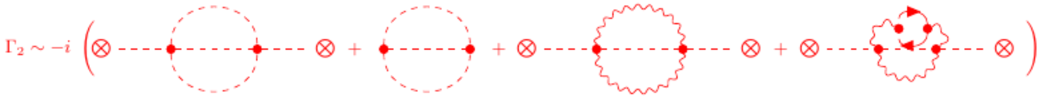

FIG. 6. Γ_2 for the photophilic case with the relevant 2PI diagrams