The thermal axion production rate, precisely

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SUBATECH

Invisibles25 Workshop

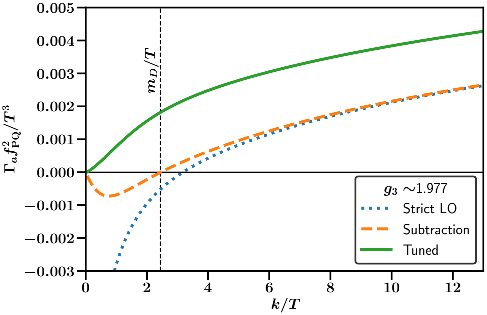


Figure: Axion production rate for $T = 0.3$ GeV

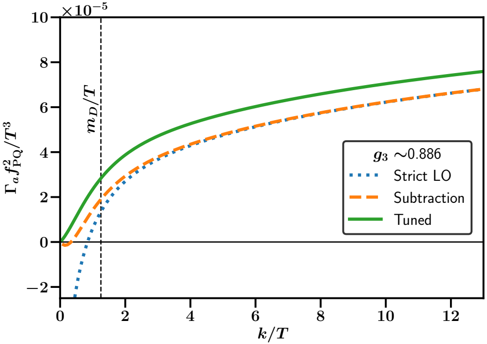
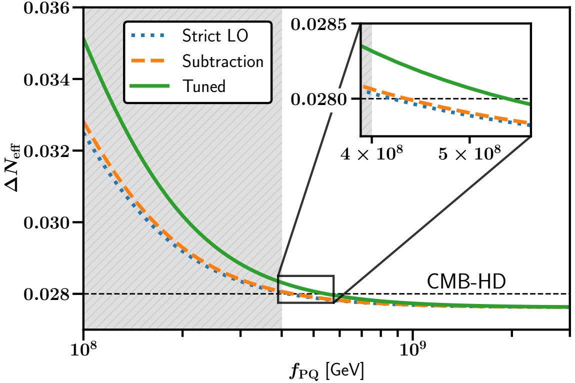


Figure: Axion production rate for $T = 10$ TeV

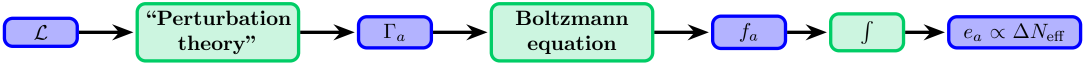
- Several methods exist to implement **medium effects**, three are shown here
- Those three methods **converge** for $k > m_{\rm D}$ and g_3 small
- They are **extrapolations** for $k < m_{\rm D}$ $\rightarrow$ how does this impact the **phenomenology**?



- Difference between Γ_a computations $\to$ different $\Delta N_{\rm eff}$ values $\to$ **"theoretical uncertainty"** on the $\Delta N_{\rm eff}$ computation

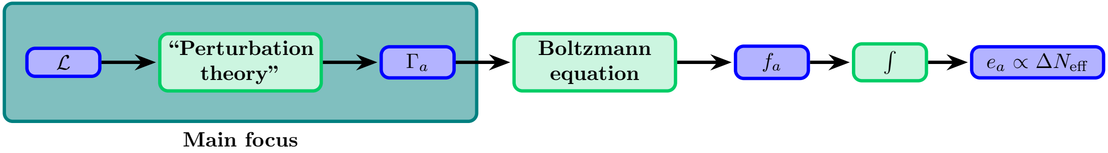
- Results on this slide and the previous published in **KB**, *J. Ghiglieri - Thermal axion production at hard and soft momenta (2404.06113)*
- More details on the axion production rate computation also on my poster

The "flowchart" of the $\Delta N_{\rm eff}$ computation is:



Most **complex** step: going from the **Lagrangian** (encoding the **interactions**) to the **thermal production rate**

The "flowchart" of the ΔN_{eff} computation is:

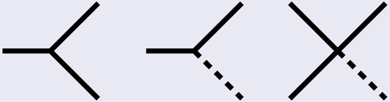


Most **complex** step: going from the **Lagrangian** (encoding the **interactions**) to the **thermal production rate**

- This is the step it would be the most interesting to **automate**

Computing the **thermal production rate** Γ_ϑ for a given particle ϑ (dashed lines) in a **thermal bath** (solid lines) involves the following steps:

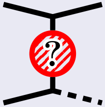
1. Obtaining the **Feynman rules**



2. Computing all **relevant processes**

3. Perform the **phase space integration** $\cong$ "averaging" the **matrix element squared** with the **thermal distributions** of particles in the thermal bath

4. Account for **medium effects**



i.e. obtaining the **thermal mass** of the **mediator**

We propose the new code `AUTOTHERM`, to be released soon in **KB**, *J. Ghiglieri, G. Jackson - (25XX.XXXXX)*

- Automatically compute the **thermal production/equilibration rate** of a **light** particle ϑ ($m_\vartheta \ll T$) in a **thermal bath** of **massless particles**
- Written in **Python** and **Mathematica**
- **Minimal user intervention** required to perform the computation

Current limitations

- Only $2 \to 2$ processes
- **Single production** (only **one** ϑ in the final state)

Possible uses

- ALP production in the early Universe
- Dark matter production in the UV or UR regime
- ...

Thanks for listening

Reproducing the results in 2404.06113 for **graviton** production:

- Requires **few** lines of code
- Only requires 2 **input files**
  1. A **configuration file**
  2. A **model file**
- Takes $\lesssim$ 5 minutes