Cosmological constraints on the Higgs portal

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Initial conditions set by inflation

- During inflation, the scalar sector of the model is specified by the potential

$$V(h,s) = \frac{\lambda_h}{4}h^4 + \frac{\lambda_s}{4}s^4 + \frac{\lambda_{sh}}{2}s^2h^2$$

- No non-minimal coupling to gravity (No higgs inflation[1], assume stability of the higgs potential[2])
- Typical magnitudes of the scalar condensates generated during inflation are

$$h_* = \mathcal{O}(0.1)\frac{H_*}{\lambda_h^{1/4}}, \qquad s_* = \mathcal{O}(0.1)\frac{H_*}{\lambda_s^{1/4}}$$

[1] See e.g. Bezrukov & Shaposhnikov (arXiv:1403.6078)

[2] Fairbairn & Hogan (arXiv:1403.6786), Enqvist et al. (arXiv:1404.3699), Herranen et al. (arXiv:1407.3141)

Thermal blocking delays the decay

- Assume inflaton decaying into SM particles and instantly reheating the Universe $\Rightarrow T^4 \simeq M_{Pl}^2 H_*^2$
- This causes all fields i coupled to thermal bath to acquire a large effective thermal mass,

$$m_i^2(T) \to m_i^2(0) + c_i T^2$$

- Both the lowest order perturbative and non-perturbative decay channels are blocked. Instead, the condensates decay by two-loop thermal effects.

Does the model allow a strong EWPT?

- The Higgs condensate thermalizes typically at $T_h \sim 10^{14}$ GeV, the singlet around $T_s \sim 10^6$ GeV.
- The fields relax to their vacua by the EW scale and allow for the baryogenesis mechanism in this model[3].
- A strong EWPT requires $\lambda_{sh} \geq 0.1$, whereas the dark matter production via freeze-out mechanism requires $10^{-2} \leq \lambda_{sh} \leq 10^{-1}$ $\Rightarrow$ Both strong EWPT and the dark matter abundance cannot be simultaneously realized in this model[4].

[3] See e.g. Cline & Kainulainen (arXiv:1210.4196)

[4] See also Alanne et al. (1407.0688)

Another option for the dark matter production

- However, if the portal coupling takes a value $\lambda_s \lesssim 10^{-7}$, the singlet s never thermalizes.
- With these values of the coupling, it is possible to slowly produce a sizeable fraction of the observed dark matter abundance via singlet condensate fragmentation and thermal Higgs scattering (the so-called freeze-in).
- Physics also below the EW scale can therefore be affected by the non-vacuum initial conditions generated by inflation.

Conclusions and Outlook

- Constraints from inflation for BSM models can be analysed.
- They can affect physics at the EW scale, and model computations need to be revisited.
- This talk was based on arXiv:1407.0659. More results for freeze-in production of dark matter are in progress and out soon.