

Inflationary constraints on Dark Matter properties

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in collaboration with

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What do we study, i.e. how to constrain the unconstrainable (by colliders)?

- ▶ Our focus is on **testing the Standard Model extensions** through a broad range of their cosmological imprints.
- ▶ We want to find **new ways to test SM extensions** weakly coupled to SM.
- ▶ In particular, we study **dark matter production** and phase transitions (**baryogenesis**).

Prelude: What have we found?

- ▶ The key new ingredient: the consistent inclusion of inflationary initial conditions for the typical scalar sector encountered in extensions of SM.
- ▶ We have found a novel interplay between inflationary dynamics and dark matter properties.
- ▶ This places stringent constraints on viable mass scales and coupling values in SM extensions.

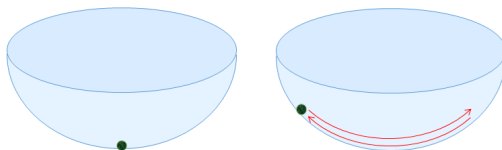
- ▶ The scalar sector of the model is specified by the potential

$$V(\Phi, s) = m_h^2 \Phi^\dagger \Phi + \lambda_h (\Phi^\dagger \Phi)^2 + \frac{1}{2} m_s^2 s^2 + \frac{\lambda_s}{4} s^4 + \frac{\lambda_{sh}}{2} \Phi^\dagger \Phi s^2$$

- ▶ Here Φ and s are, respectively, the usual Standard Model Higgs doublet and a [real singlet scalar](#).
- ▶ The coupling between Φ and s acts as a portal between the Standard Model and an unknown Dark Sector (the so-called [Higgs portal](#)). We take $\lambda_{sh} \lesssim 10^{-7}$.

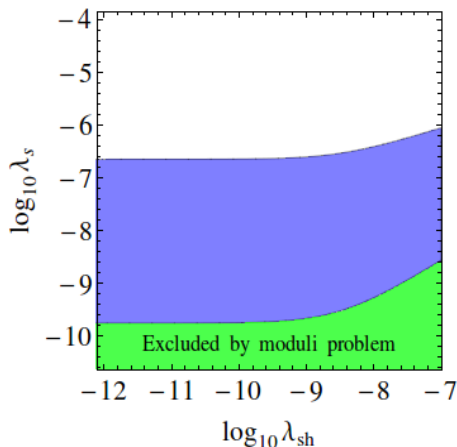
Field dynamics during Cosmic Inflation

- ▶ The scalar fields will typically acquire fluctuations proportional to the **inflationary scale**, $h, s \simeq H_* \lesssim 10^{14}$ GeV.
- ▶ When do the fields **relax** down to their minima? What happens to the **energy stored in the fields**?
- ▶ It is possible to produce the observed dark matter abundance via **particle production from a background field**!



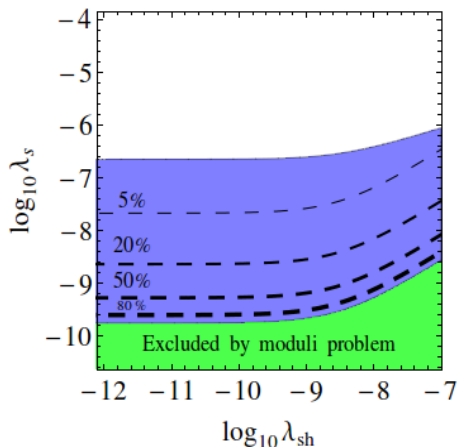
A (quantum) marble in a bowl.

Dark Matter from Primordial Field



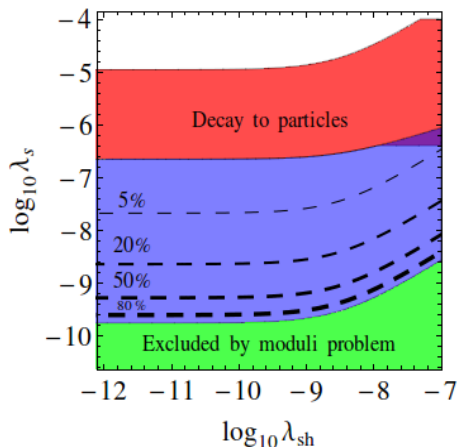
- In this figure $H_* \simeq 10^{10}$ GeV and $m_s = 20$ MeV.

Dark Matter from Primordial Field



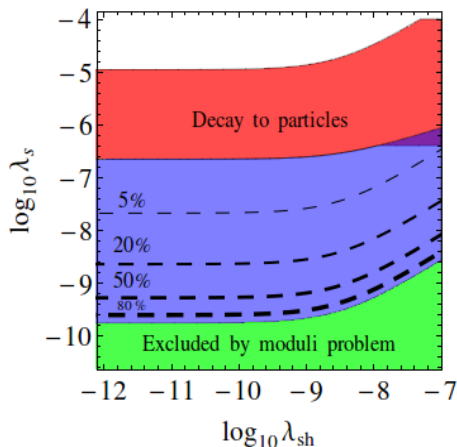
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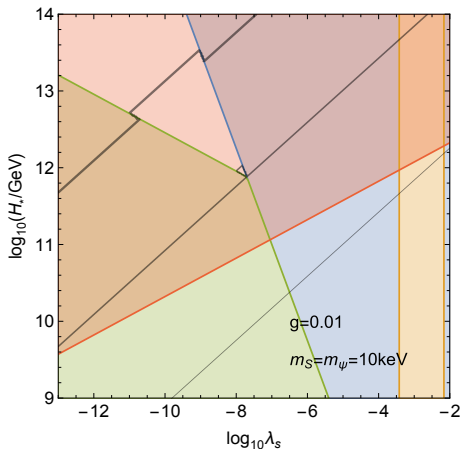


- However, **too much entropy** in the produced particles!

Extensions of the simplest model

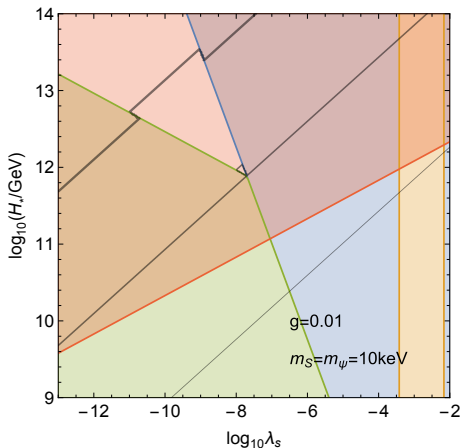
- ▶ What if the dark sector contained **more fields**?
- ▶ Consider the interaction $gs\bar{\psi}\psi$ between singlet scalar and **singlet fermion**.
- ▶ The primordial scalar field can now **decay into fermions** instead of decaying into quanta of its own field.

Preliminary results



- Red: Excluded by entropy production, Yellow (Green): Decay to fermions in quartic (quadratic) potential, Blue: Decay to scalars.

Preliminary results



- Contours from thickest to thinnest: 1, 10^{-6} , 10^{-9} of the **observed DM abundance**.

- ▶ It seems that a great majority of the observed DM abundance has to be produced by **other mechanisms**.
- ▶ The formation of primordial scalar fields however puts **stringent constraints** on model parameters.
- ▶ New physics even with **tiny couplings** to the SM can be constrained by carefully investigating their dynamics both during and after inflation (remember: $\lambda_{\text{sh}} \lesssim 10^{-7}$).

Take-home message

Cosmic inflation can be used to constrain the high-energy regime of extensions of the Standard Model.