Dark matter from scalar field fluctuations

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Talk based on PRL 123, 061302 (2019) (1905.01214)
(+ 1811.02586 & 1904.11917)

Online Newton 1665 Seminar
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Cosmic inflation

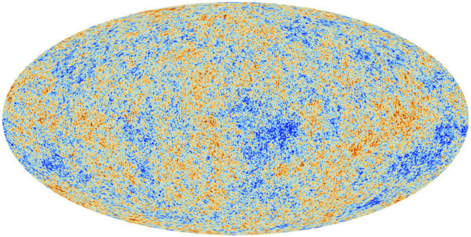

Image: Planck/ESA

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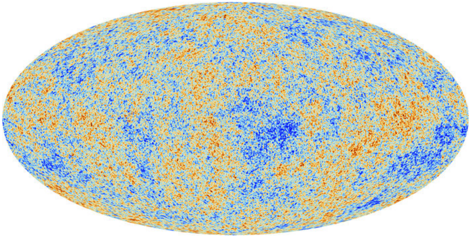

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- Must explain the observed curvature perturbations (+ several fine-tuning problems) $\Rightarrow$ Cosmic inflation
- Assume standard cosmology: inflation, reheating, hot Big Bang epoch

Scalar fields in de Sitter space

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- Assume the field is not the inflaton field but a spectator field

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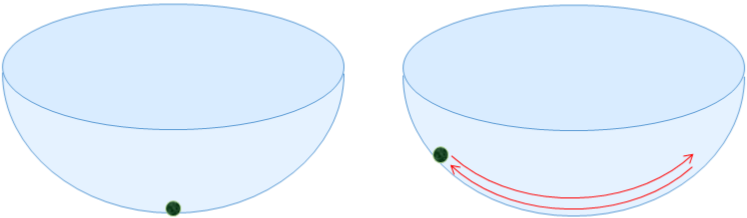

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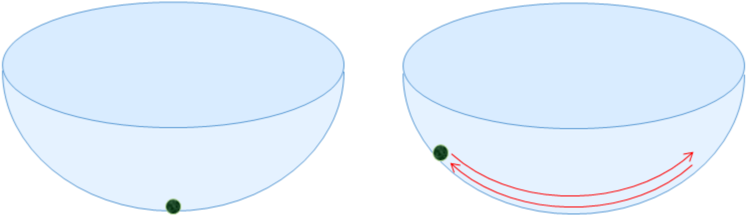

- The scalar field starts to perform random walk

Distribution of field values

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- What is the distribution of field values at the end of inflation?

Stochastic approach

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$$P(\chi) = Ce^{-\frac{8\pi^2}{3}\frac{V(\chi)}{\chi^4}}$$

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- Relaxation time scale: $N \sim \frac{H_*^2}{m^2}$

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Relaxation time

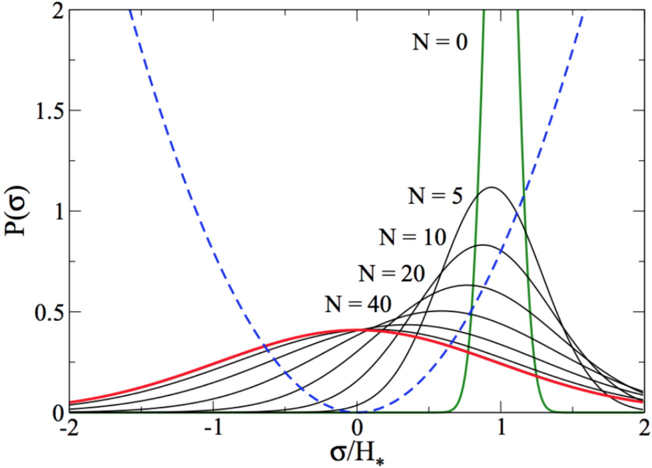

Image: Enqvist et al. (1205.5446)

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- Note that the energy density is a position-dependent quantity

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- The simplest possible dark matter model

Scalar field sources dark matter

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$$\Omega_\psi h^2 = \Omega_\psi h^2 \left(\chi_*, m, m_\psi, \Gamma_{\chi\to\psi\bar{\psi}}\right)$$

- Other sources (such as freeze-in[2]) can contribute to the final DM abundance, too

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Dark matter perturbations

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- Are the DM perturbations adiabatic or isocurvature?

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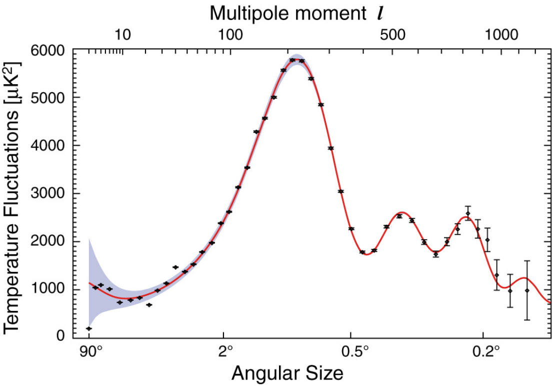
- Isocurvature between CDM and radiation is defined as

$$S \equiv \frac{\delta\rho_{\rm CDM}}{\rho_{\rm CDM}} - \frac{3}{4}\frac{\delta\rho_{\gamma}}{\rho_{\gamma}}$$

- This quantity describes how much the CDM perturbations differ from those in radiation

DM isocurvature vs. observations



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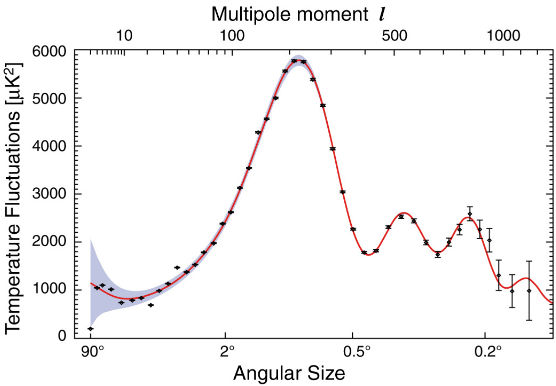

- Non-observation of DM isocurvature places stringent constraints on this type of scenarios

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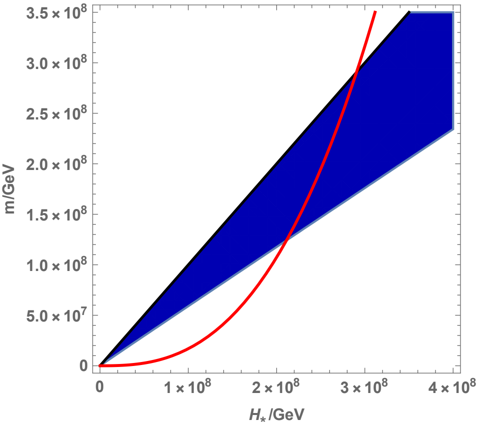
where

$$\mathcal{A}_{\rm iso} = 4\,(n_{\rm iso}-1)\,e^{-2N(k_*)(n_{\rm iso}-1)}$$

$$n_{\rm iso}-1 = \frac{2}{3}\frac{m^2}{H_*^2}$$

Simplest scenario vs. observations



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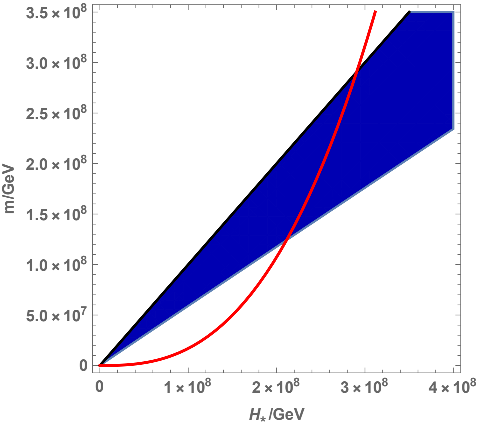

- The constraints can be satisfied $\Rightarrow$ See more: 1905.01214

Implications for observations

Testability of the scenario

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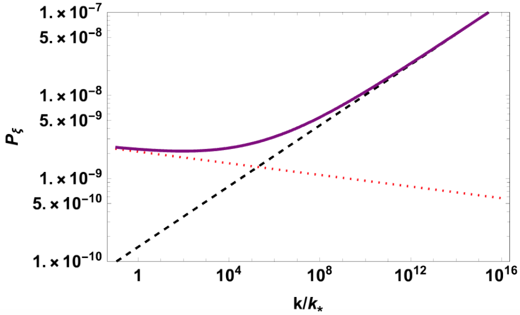

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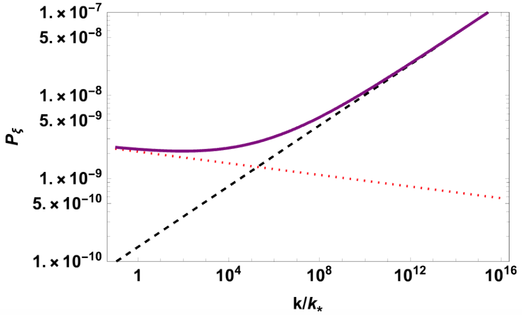
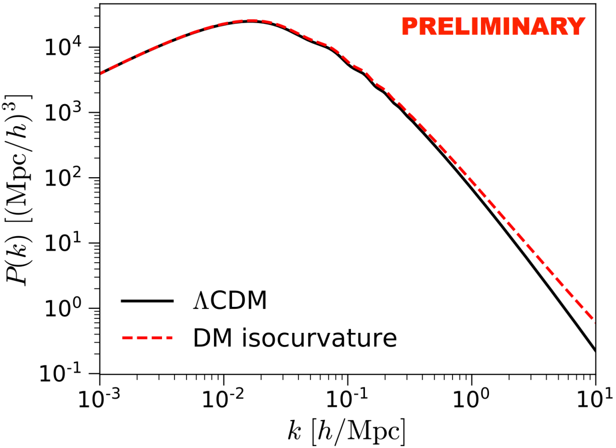


More structure at small scales!

Matter power spectrum

Image: K. Boddy



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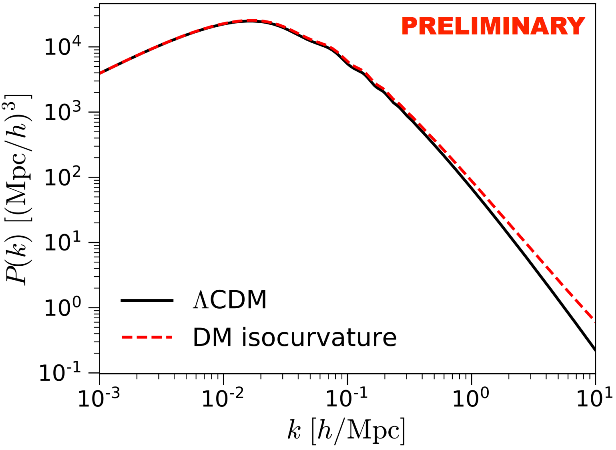

Work in progress!

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- Such scalars can constitute all DM or source it
- The scenario can be tested with observations of the large scale structure