

# Inflationary Model Building

$$\mathcal{L}_{\text{eff}}(\phi) = -\frac{1}{2}(\partial\phi)^2 - \frac{1}{2}m^2\phi^2 - \frac{1}{4}\lambda\phi^4 - \underbrace{\sum_{p=1}^{\infty} \left[ \lambda_p \phi^4 + \nu_p (\partial\phi)^2 \right] \left( \frac{g\phi}{\Lambda} \right)^{2p}}_{\text{In many models there is a sensitivity to physics near the Planck scale (e.g. Large field models).}} + \dots,$$

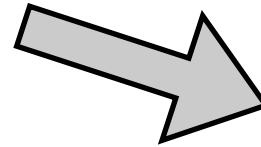
In many models there is a sensitivity to physics near the Planck scale (e.g. Large field models).

One approach is to construct explicit models (e.g. in string theory) where such corrections can be calculated.

Example (still consistent with data): **INFLATON AS AXION**

$$S_{10}^{IIB} = \frac{1}{(2\pi)^7 \alpha'^4} \int d^{10}x \sqrt{-G} \left[ \frac{1}{g_s^2} \left( R[G] - \frac{1}{2} |H_3|^2 \right) + \frac{1}{2} |F_3|^2 \right] + \dots$$

Gauge invariance in higher dimensions



$$\int d^4x \sqrt{-g_E} \frac{1}{2} f^2 (\partial_\mu c)^2$$

Shift symmetry in lower dimensions

Shift symmetry makes small parameters “natural”

# B-modes and the Scale of Inflation

However, a common feature of such approaches is the existence of additional degrees of freedom (scalars, vectors, tensors).

Do these lead to other **\*competitive\*** sources of B-modes?

Does a B-mode detection tell us the scale of inflation?

$$H_I = 3 \times 10^{-5} \left( \frac{r}{0.1} \right)^{1/2} m_p \quad ?$$

If inflation were the only primordial source the answer would be yes.

**But additional fields can lead to B-mode signals,**

(much work by Barnaby, Peloso, Mirbabayi, Silverstein, Shiu, Sorbo, Senatore, Watson, Zaldarriaga, many others...)

**Example:**

$$\mathcal{L}_{hidden} = -\frac{1}{2}(\partial\chi)^2 - U(\chi) - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{\chi}{4f}F_{\mu\nu}\tilde{F}^{\mu\nu}$$

Additional Scalar

Additional Vector

Does a B-mode detection tell us the scale of inflation?

$$H_I = 3 \times 10^{-5} \left( \frac{r}{0.1} \right)^{1/2} m_p \quad ?$$

Answer is always YES!

Theoretical consistency of inflation and observations (e.g. power spectrum and non-gaussianity) require this to be the case.

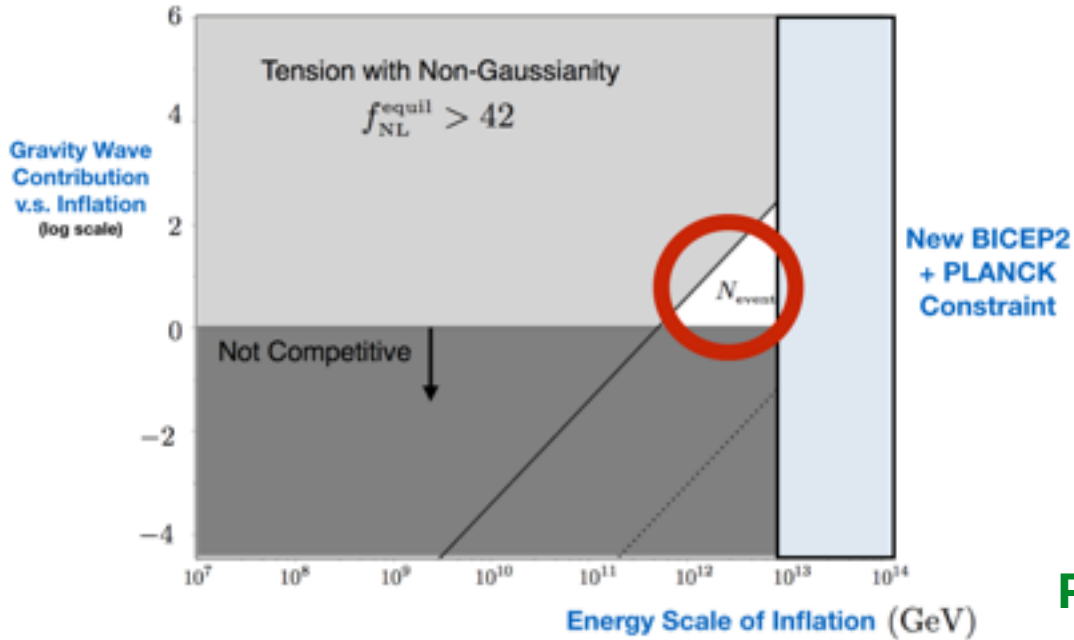
Ozsoy, Sinha, and Watson [arXiv:1410.0016](#) [Phys Rev. D91 (2015)]

Mirbabayi, Senatore, Silverstein, and Zaldarriaga [arXiv:1412.0665](#) [Phys Rev. D91 (2015)]

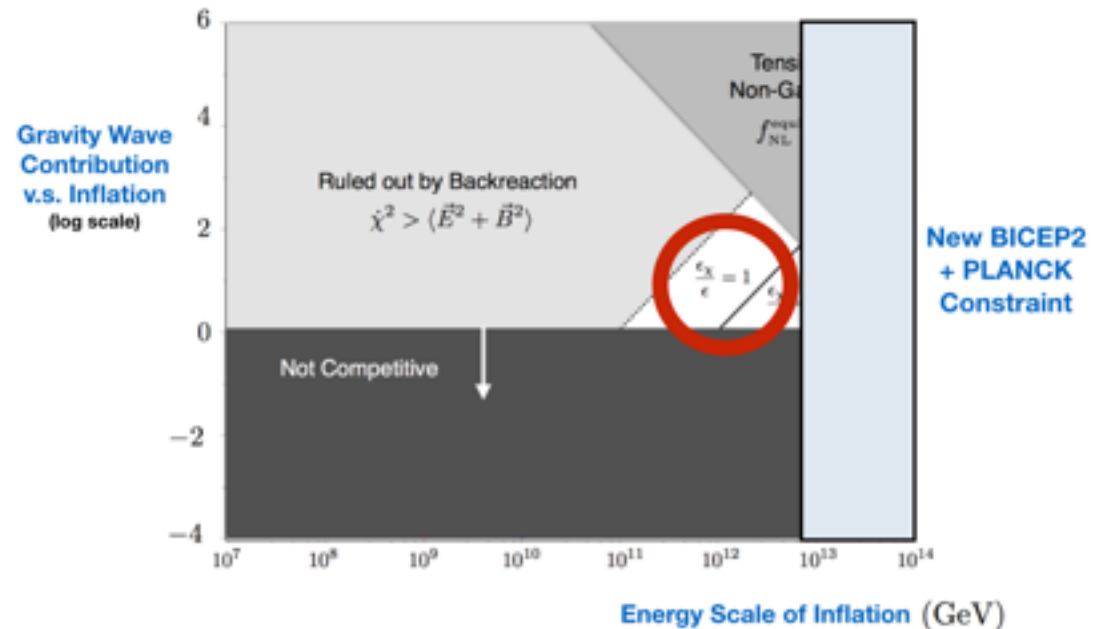
# Worst case scenarios

Figures from: Ozsoy, Sinha, and Watson arXiv:1410.0016

## Production from direct coupling to inflaton



## Production from gravitational coupling



**A B-mode detection of primordial origin still tells us the scale of inflation.**