

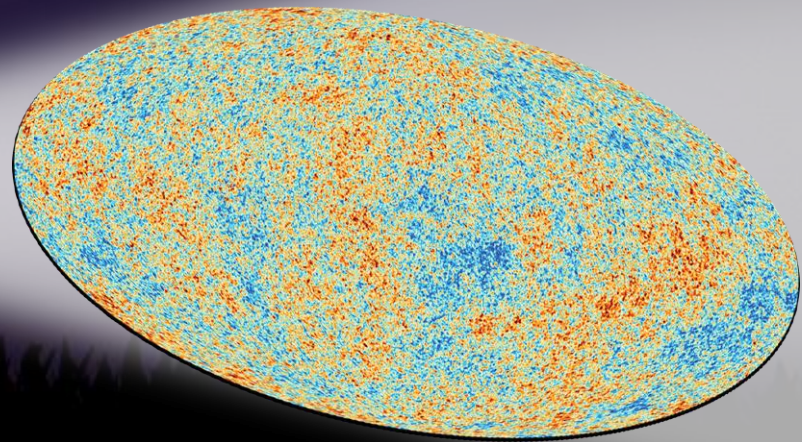
# POST-INFLATIONARY COSMOLOGY: GRAVITATIONAL WAVES VS LABORATORY SEARCHES

Based on:

A. Ghoshal, LH, A. Paul, *submitted to JHEP* [[ArXiv: 2208.01670](#)]

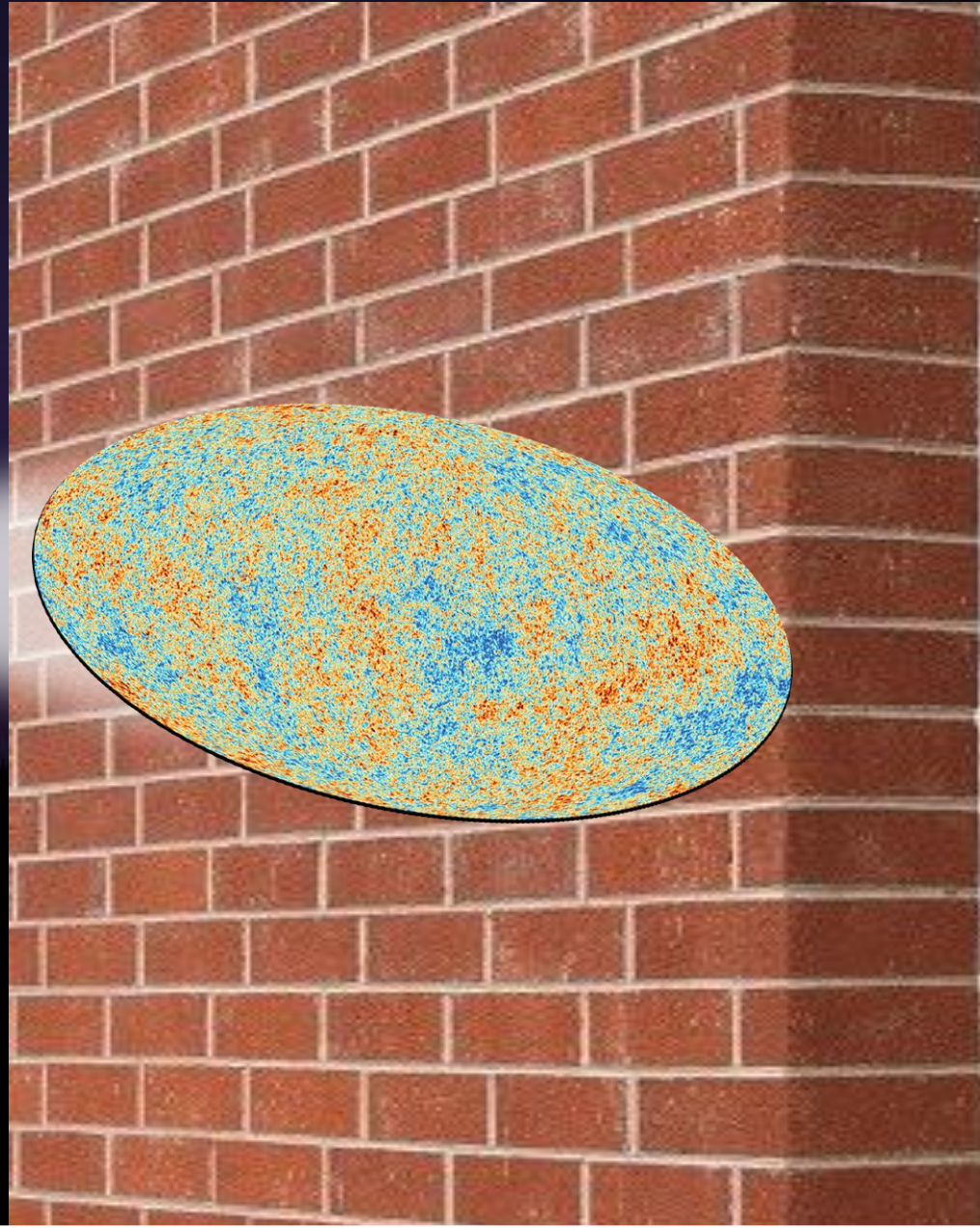
How far can we look back ?

CMB  
Perturbations

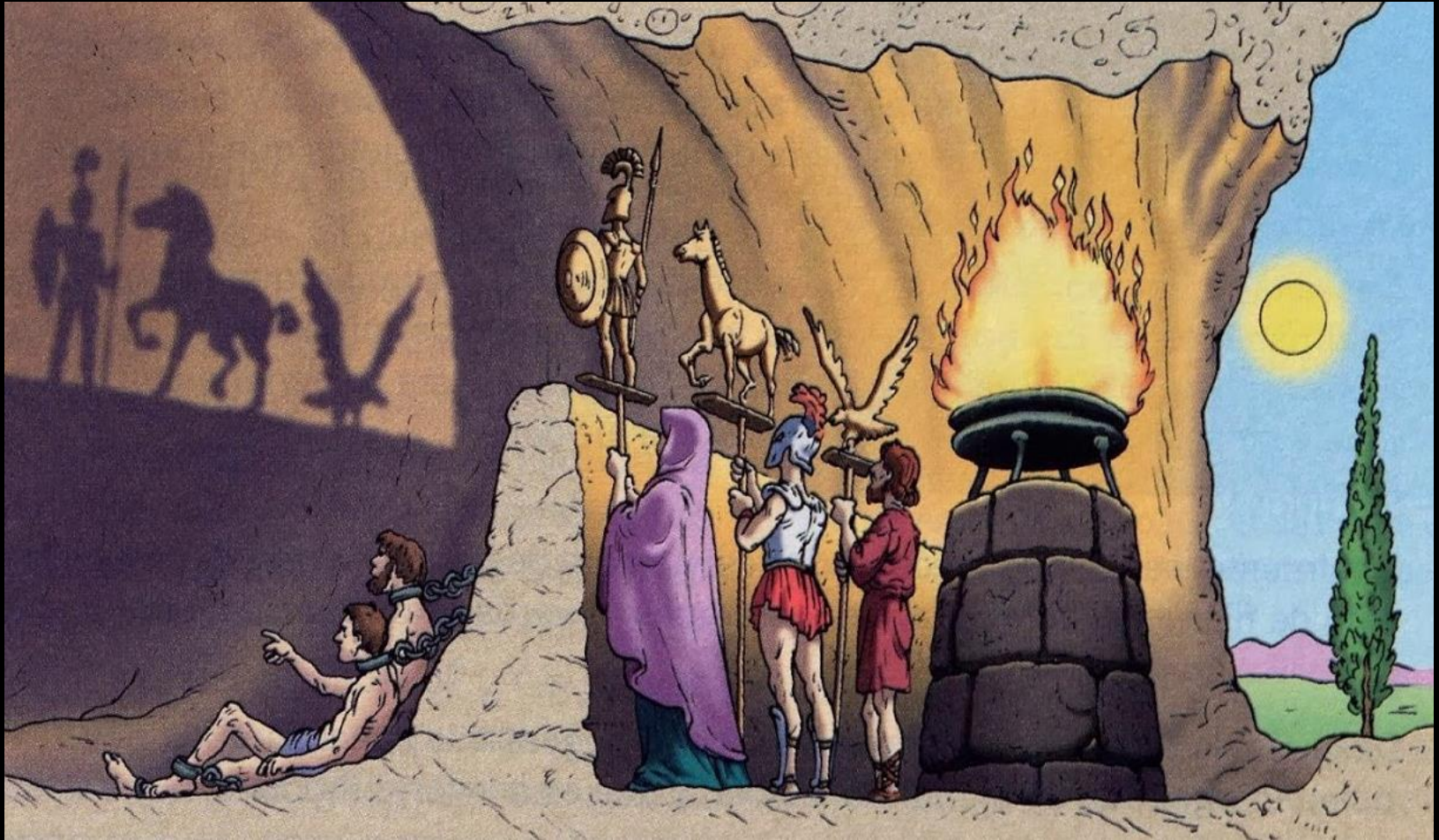


How far can we look back ?

The oldest  
optical picture ever...

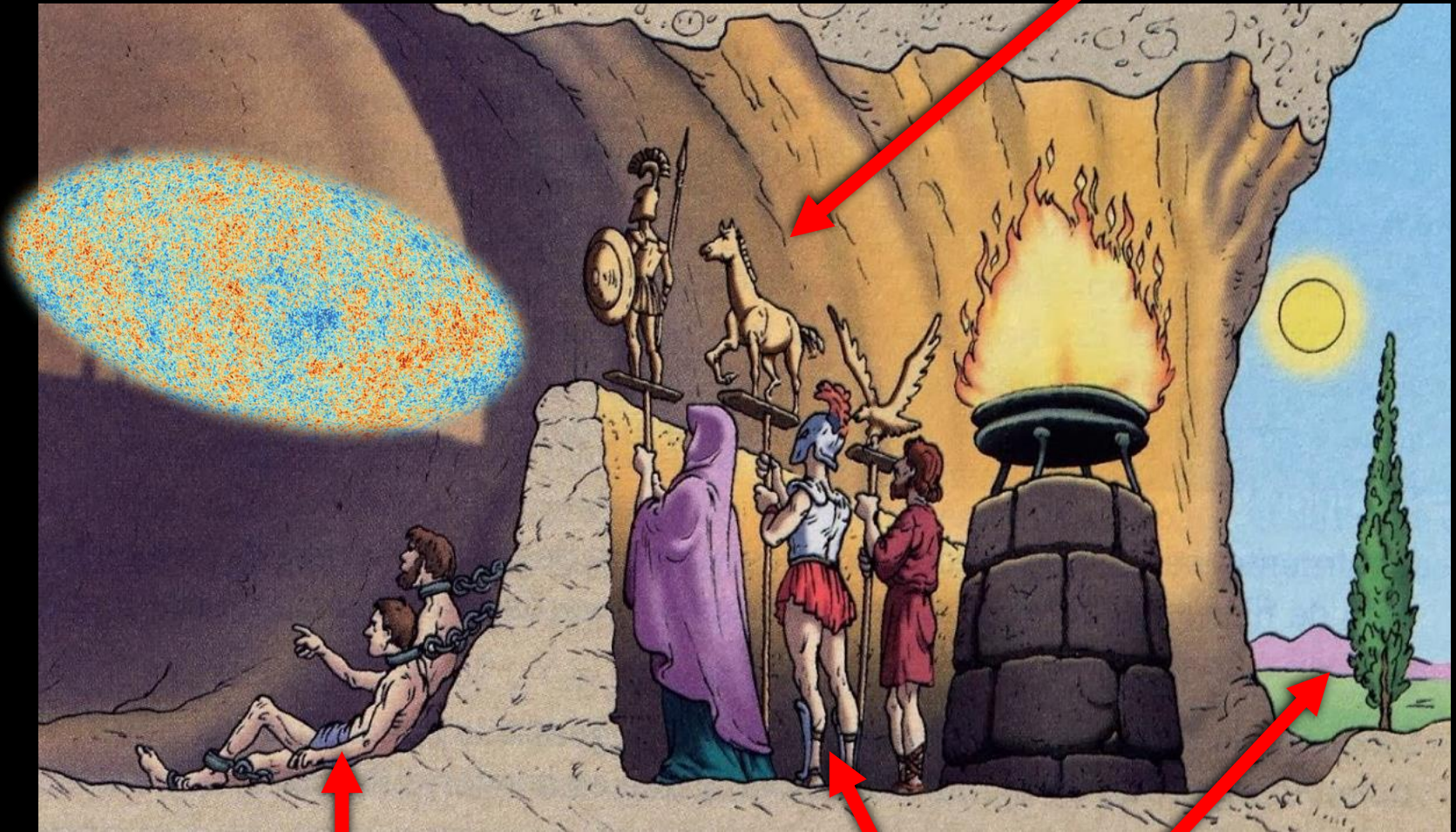


# Allegory of the Cave...



# Allegory of the Cave...

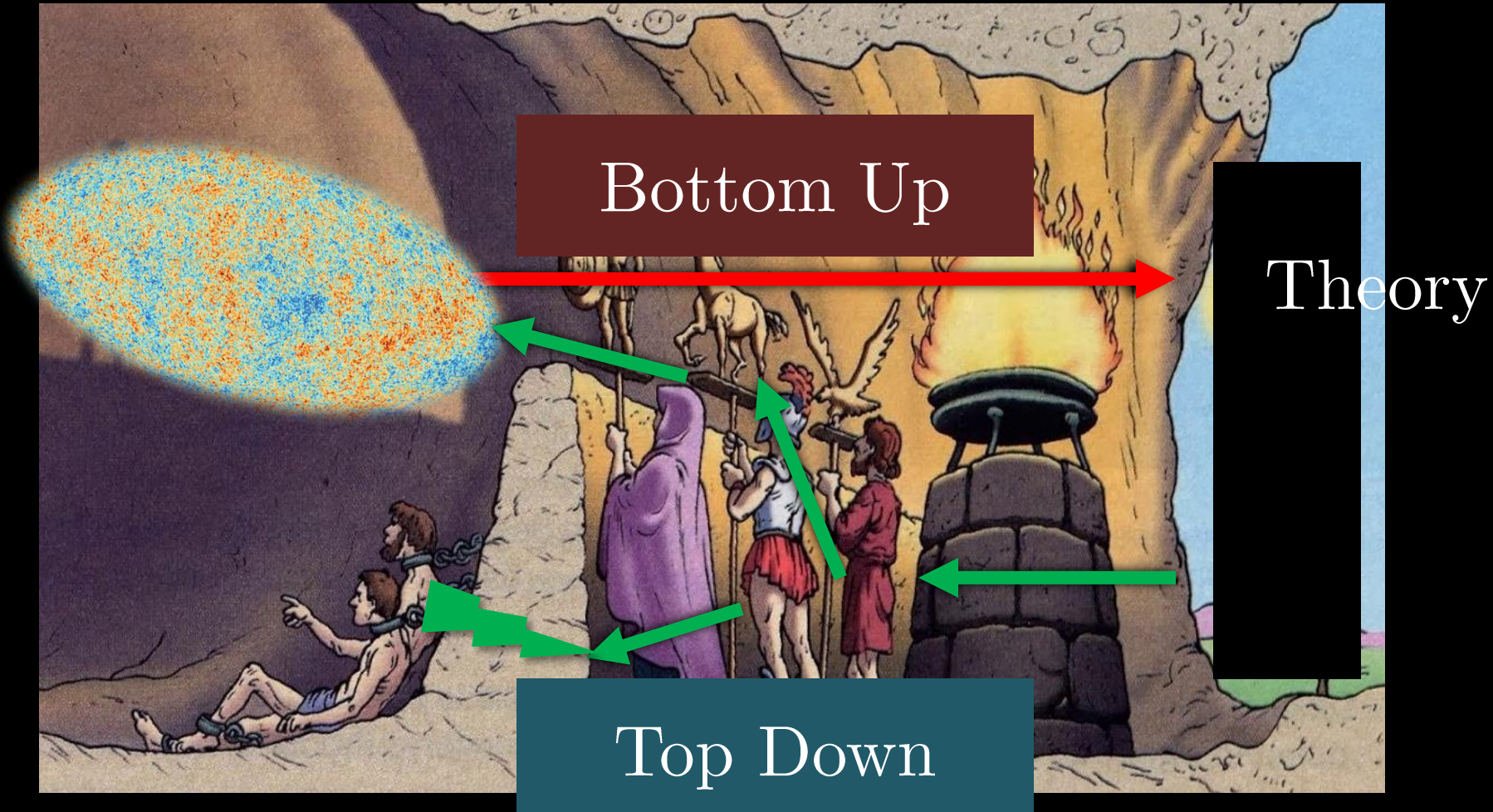
$\Lambda$ CDM



Us

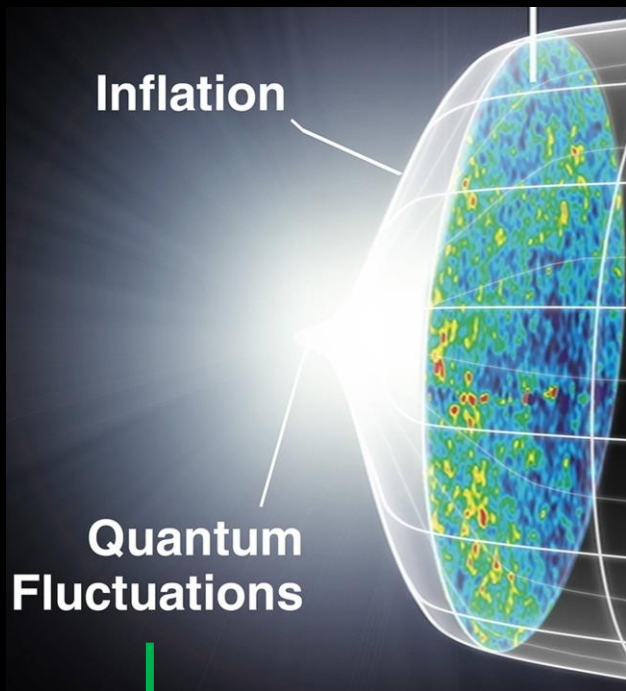
Nature

# Allegory of the Cave...

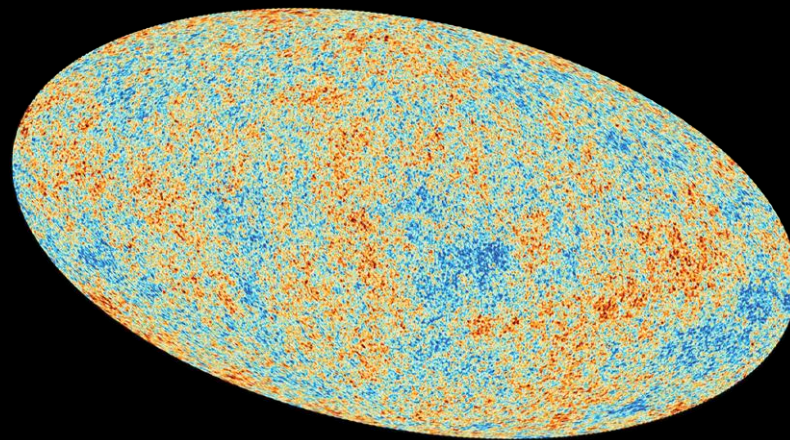


Find alternative probes

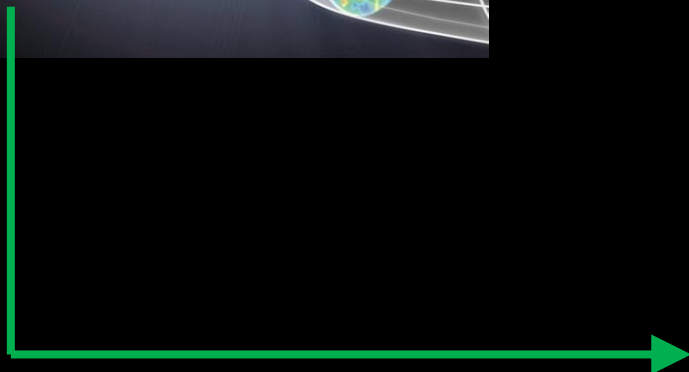
How far can we look back ?



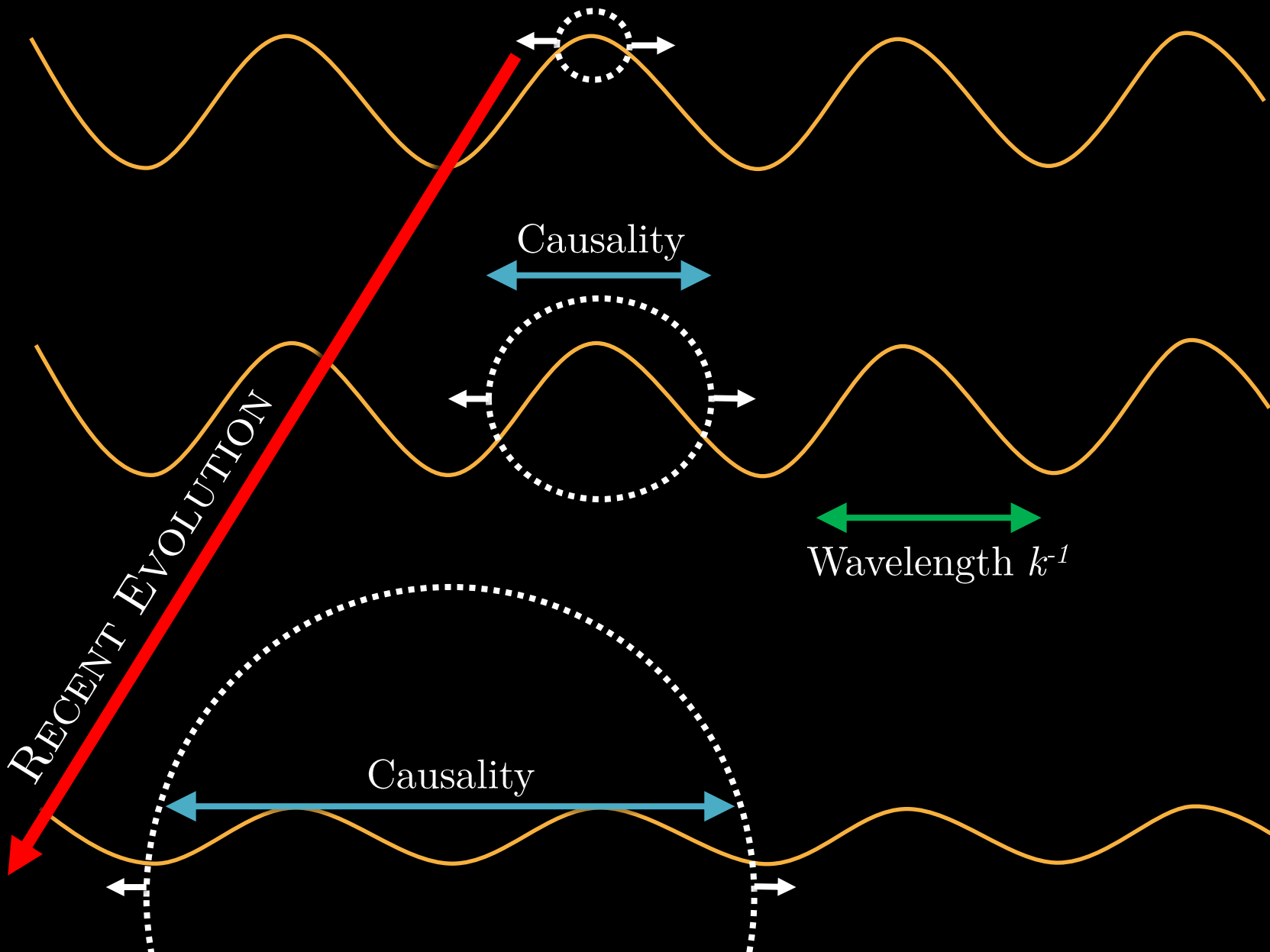
CMB  
Perturbations



Primordial  
Perturbations

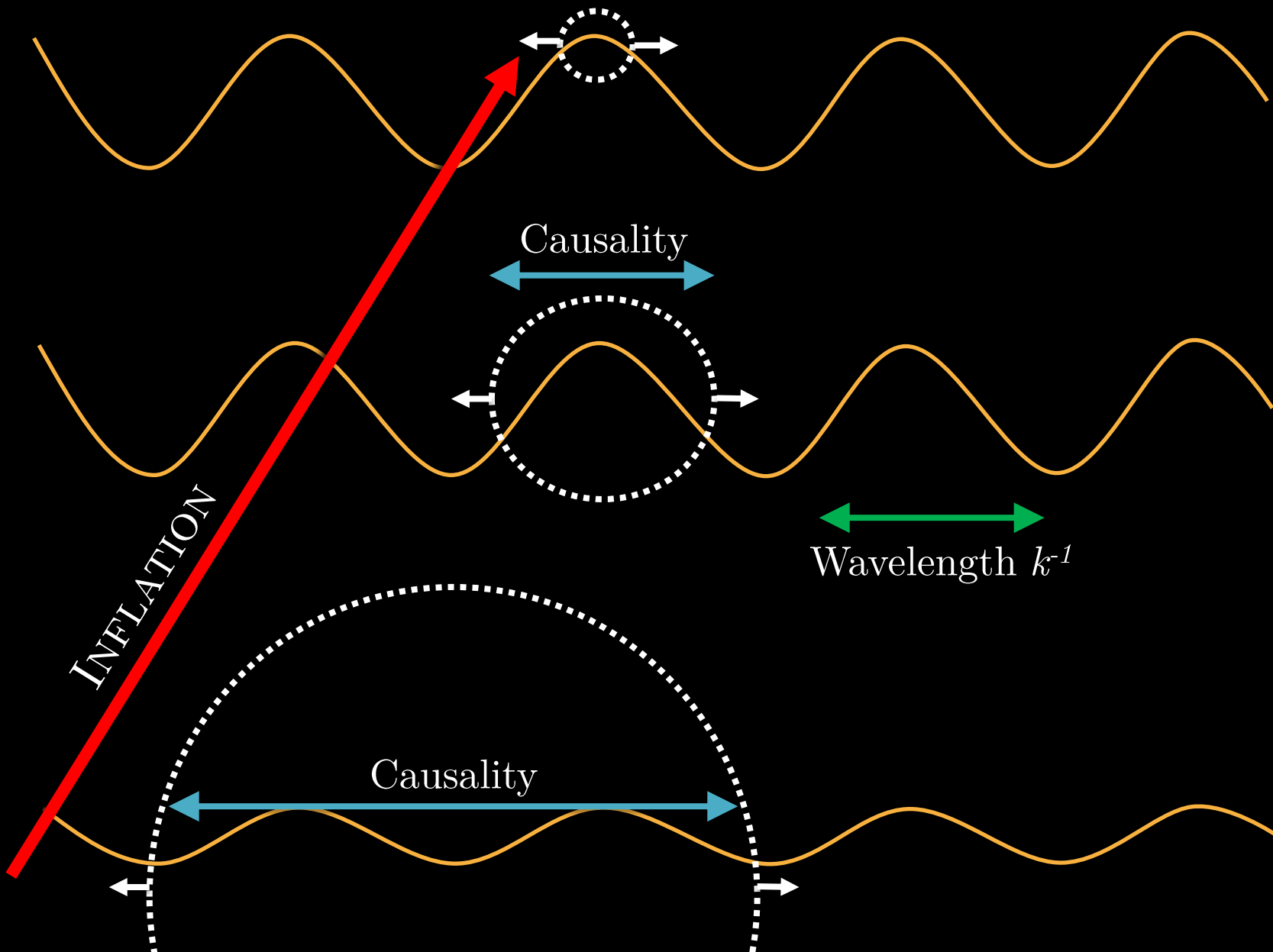


# PRIMORDIAL PERTURBATION EVOLUTION

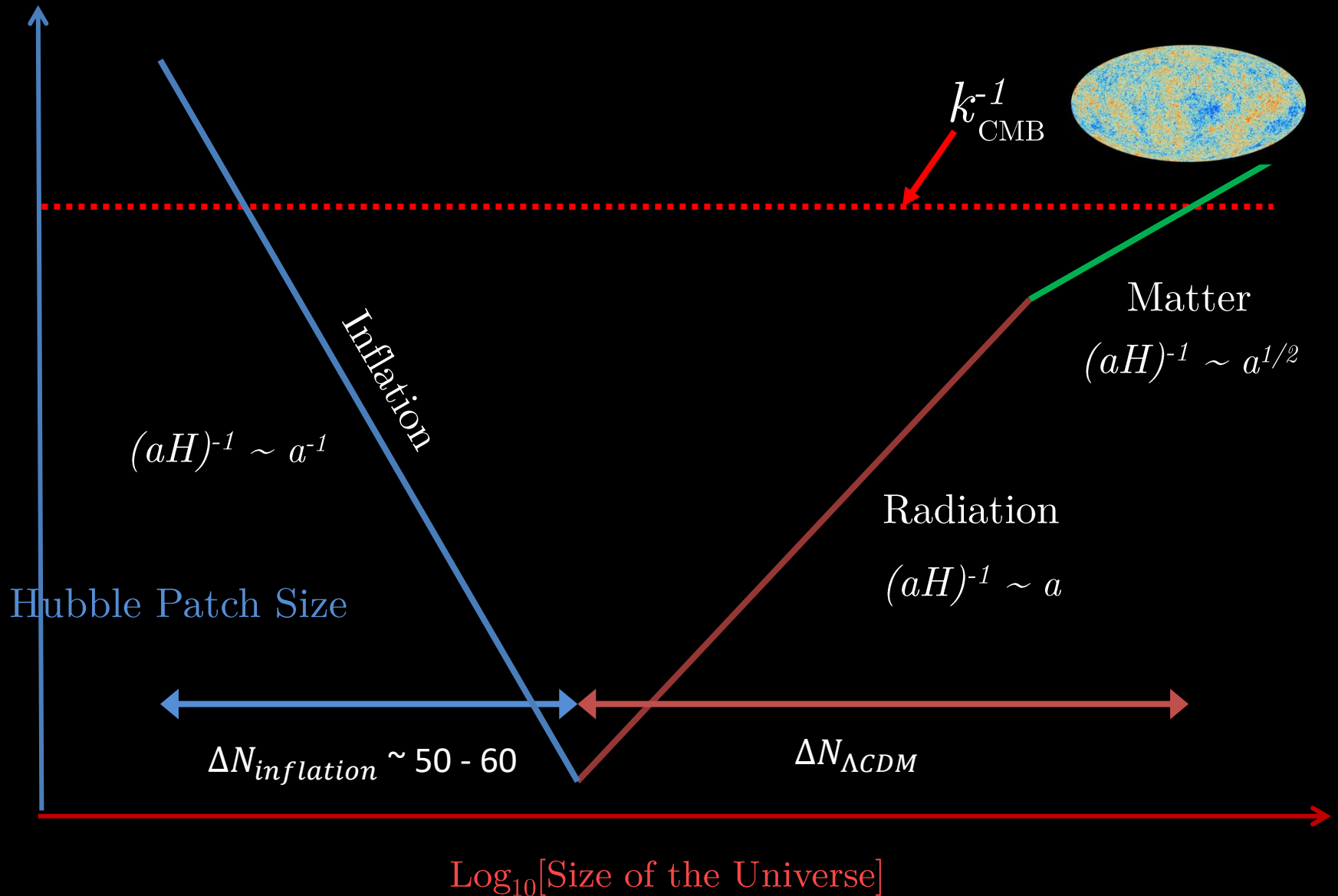




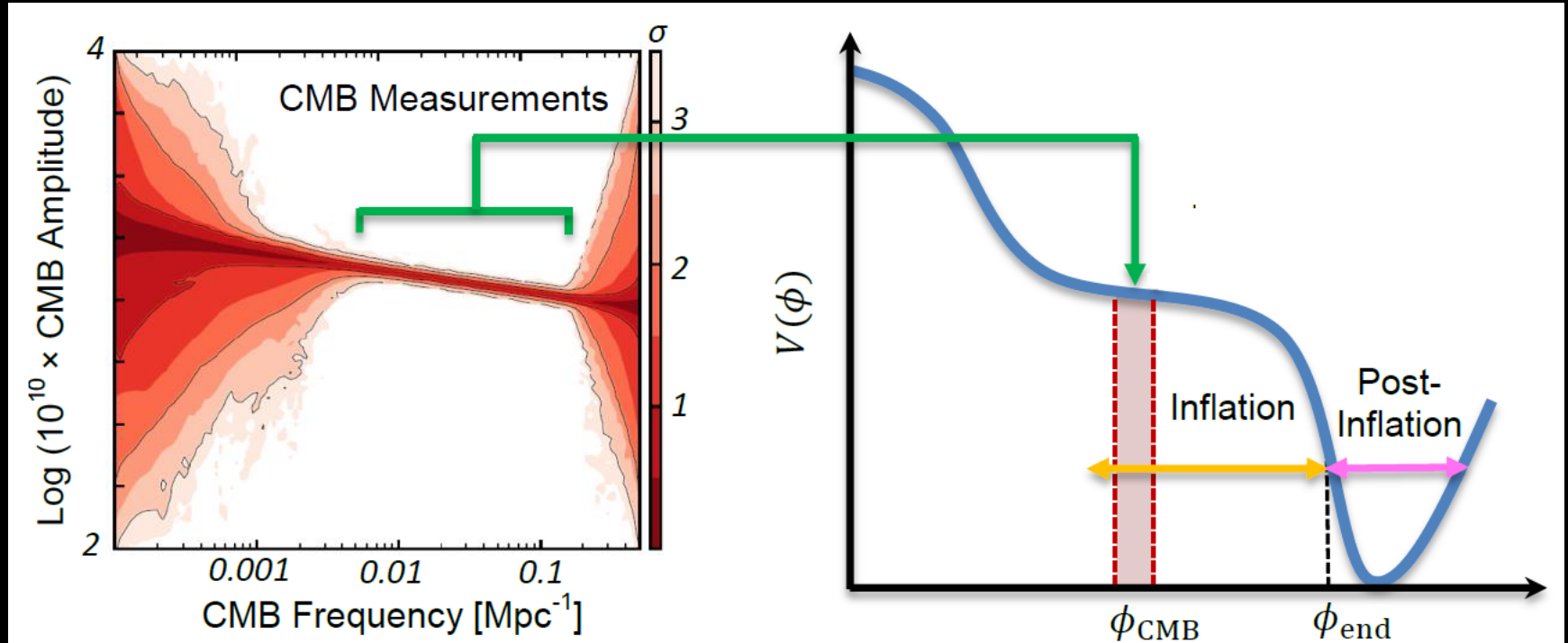
# PRIMORDIAL PERTURBATION EVOLUTION



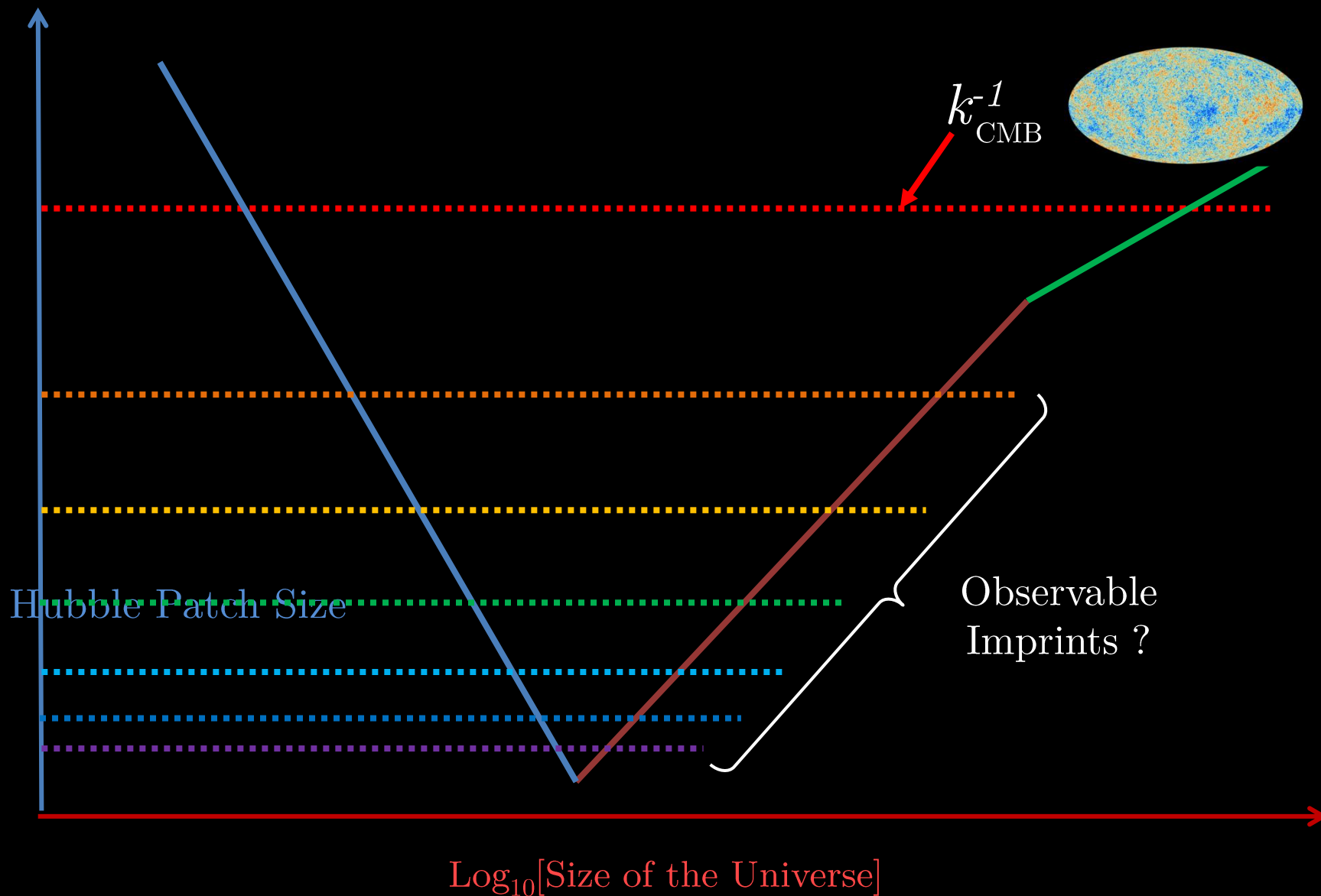
# PRIMORDIAL PERTURBATION EVOLUTION



# PRIMORDIAL PERTURBATION EVOLUTION



# PRIMORDIAL PERTURBATION EVOLUTION

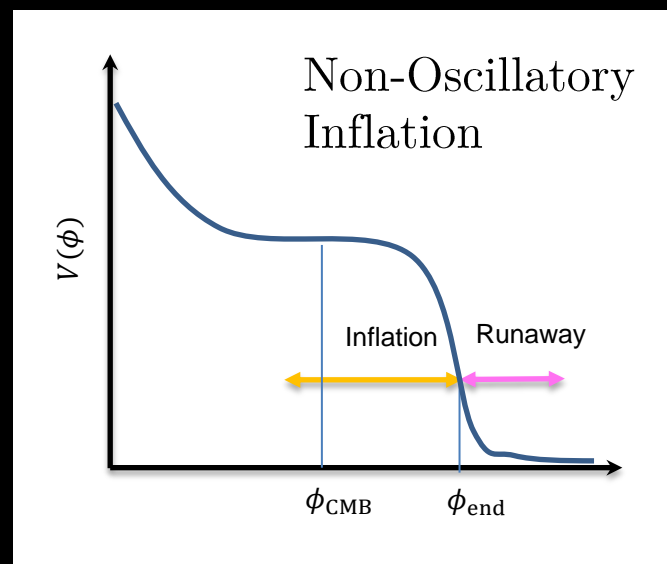
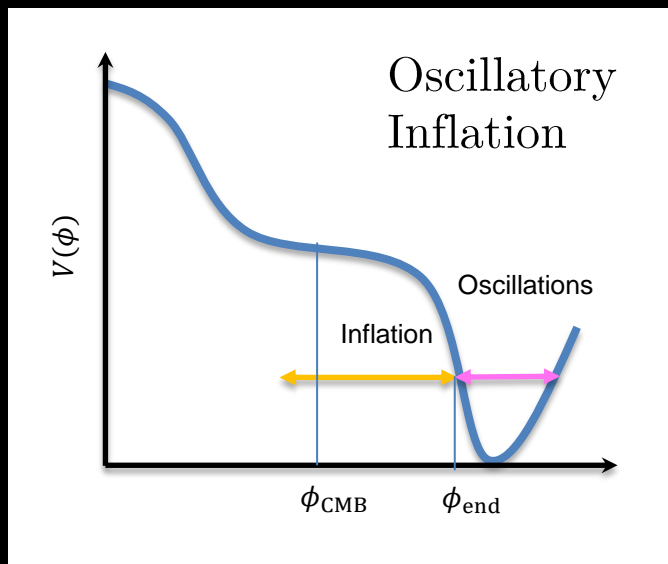


Standard Inflation scenario:

Inflation  $\rightarrow$  Radiation dom.  $\rightarrow$  Matter dom.

$\rightarrow$  GW spectrum too low to be detected

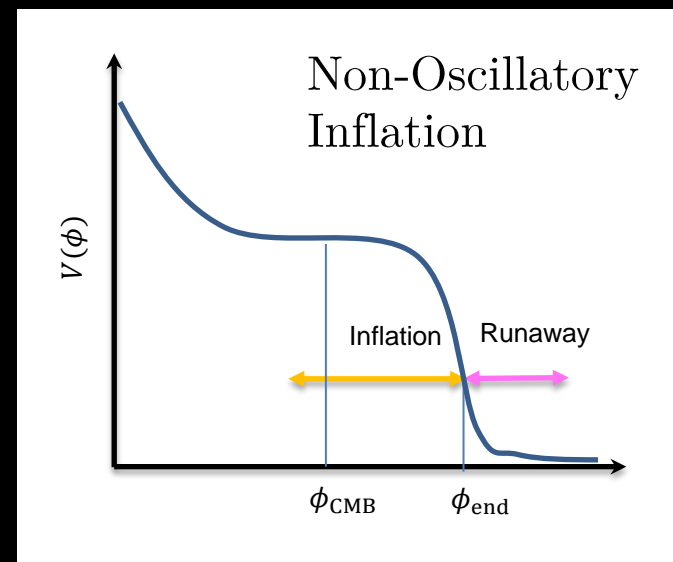
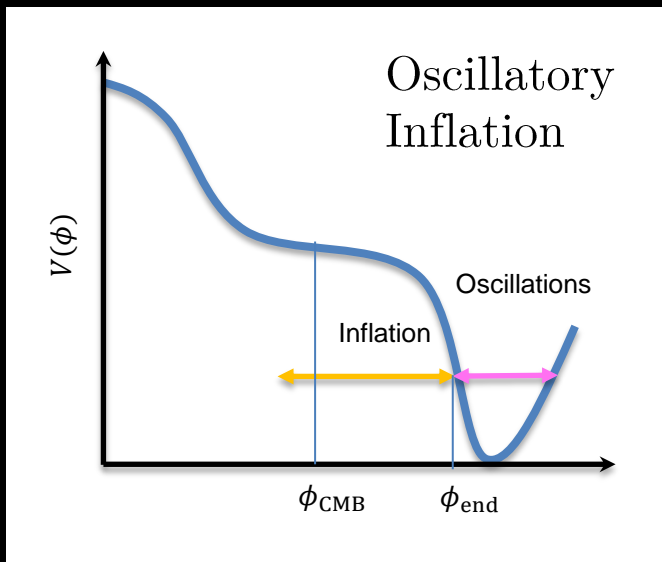
Not all inflation scenarios end up that way...



# Non-Oscillatory Inflation:

→ **Reheating** harder to achieve

Gravitational production, instant pre-heating, transfer of energy to other scalar fields...

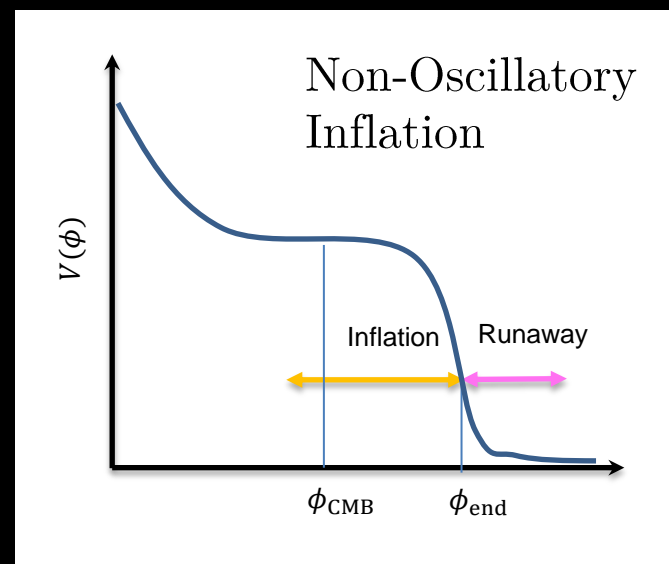
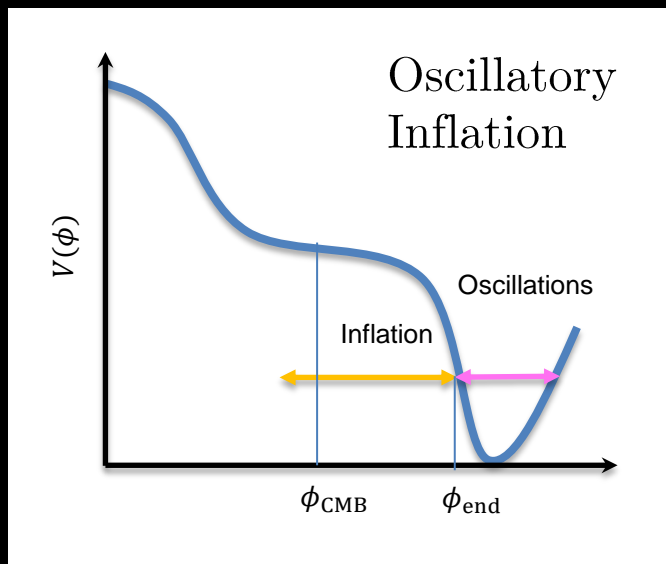


# Non-Oscillatory Inflation:

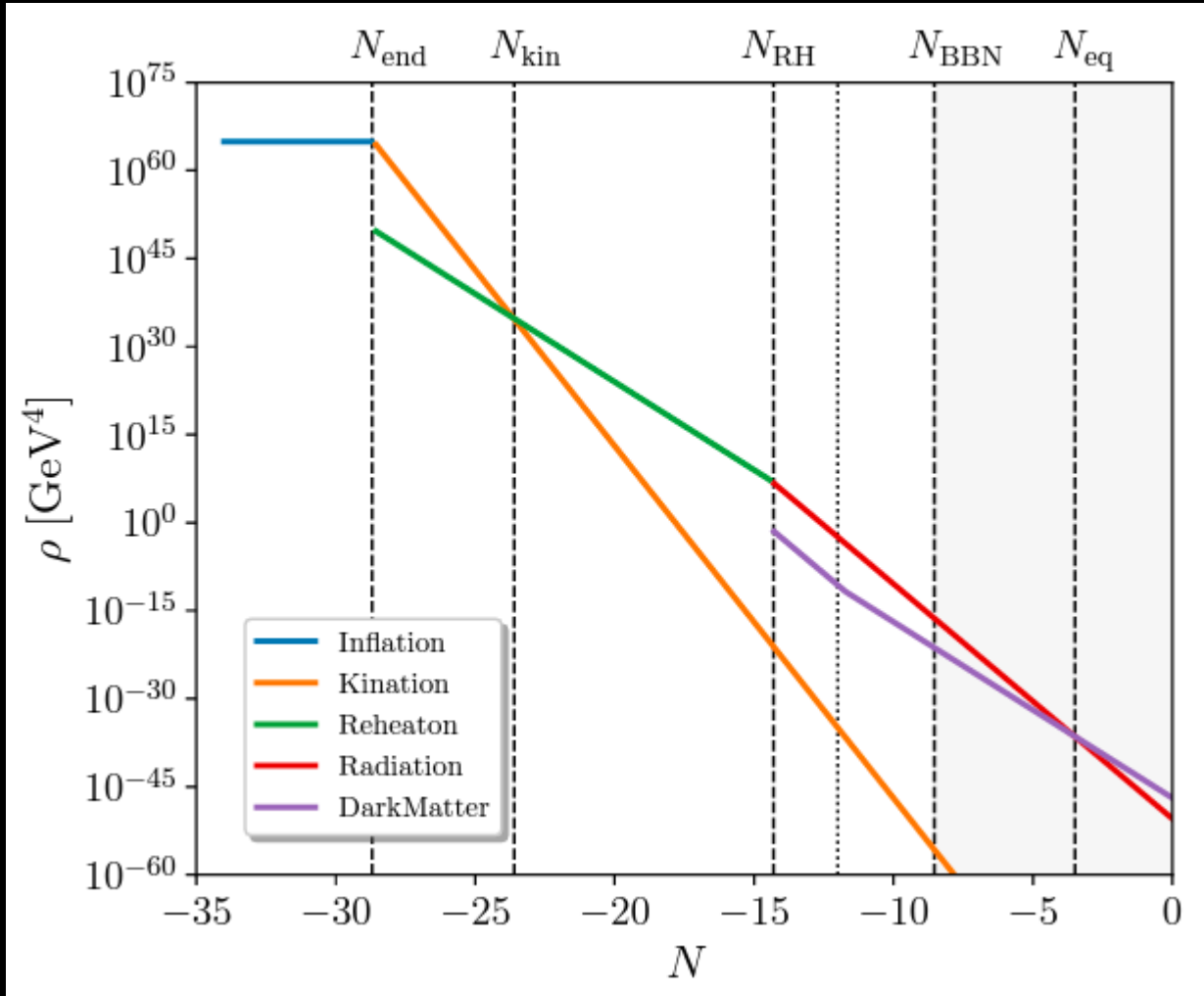
→ **Reheating** harder to achieve

→ Dynamics dominated by the rolling inflaton → period of **kination**

$$(w_{\text{kin}} = 1, \rho_{\text{kin}} \propto a^{-6})$$



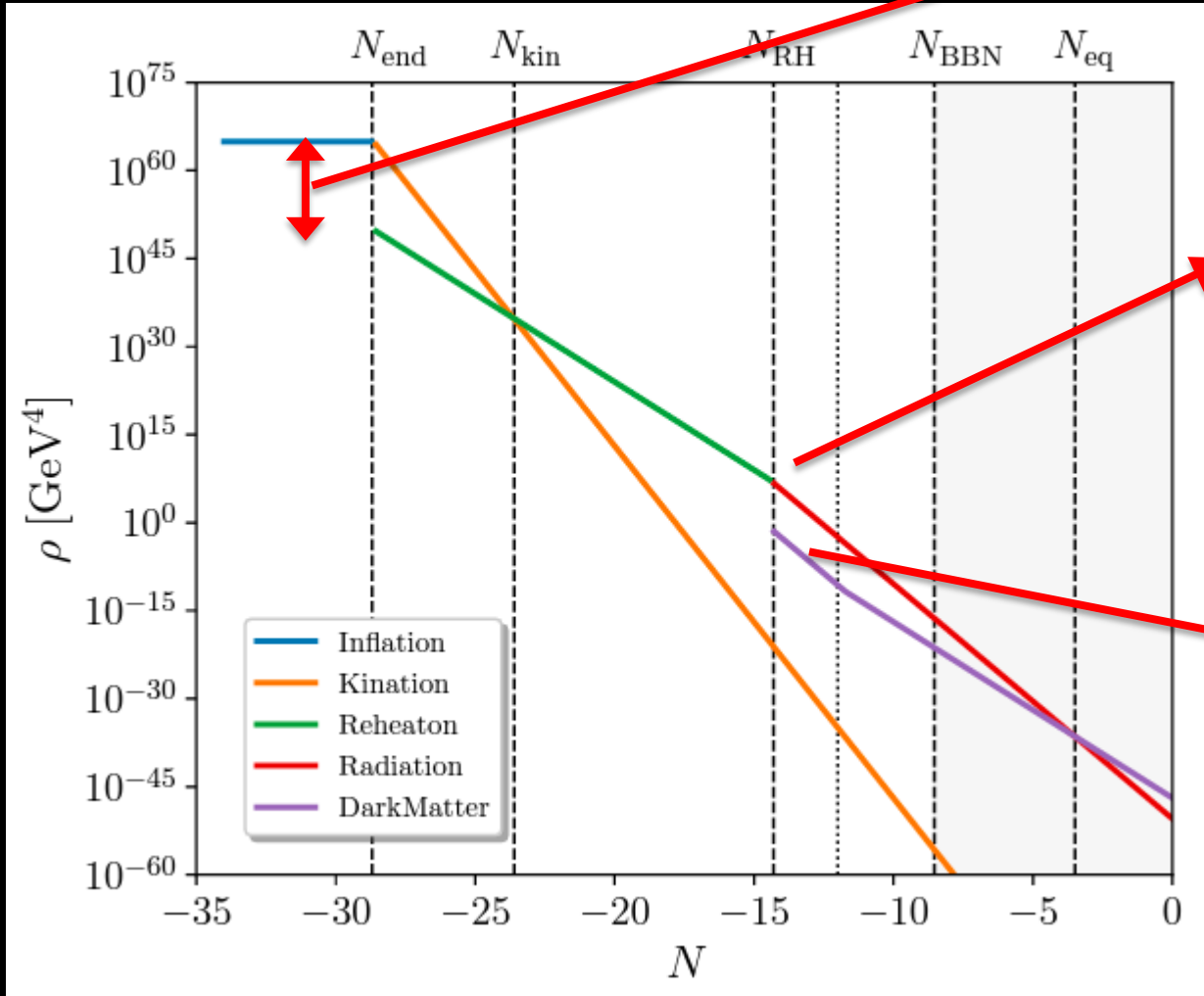
# Our scenario:





Our scenario:

Energy fraction  $\eta$




Decay of the reheaton at  $H = \Gamma_S$

DM produced Out-of-eq By reheaton decay

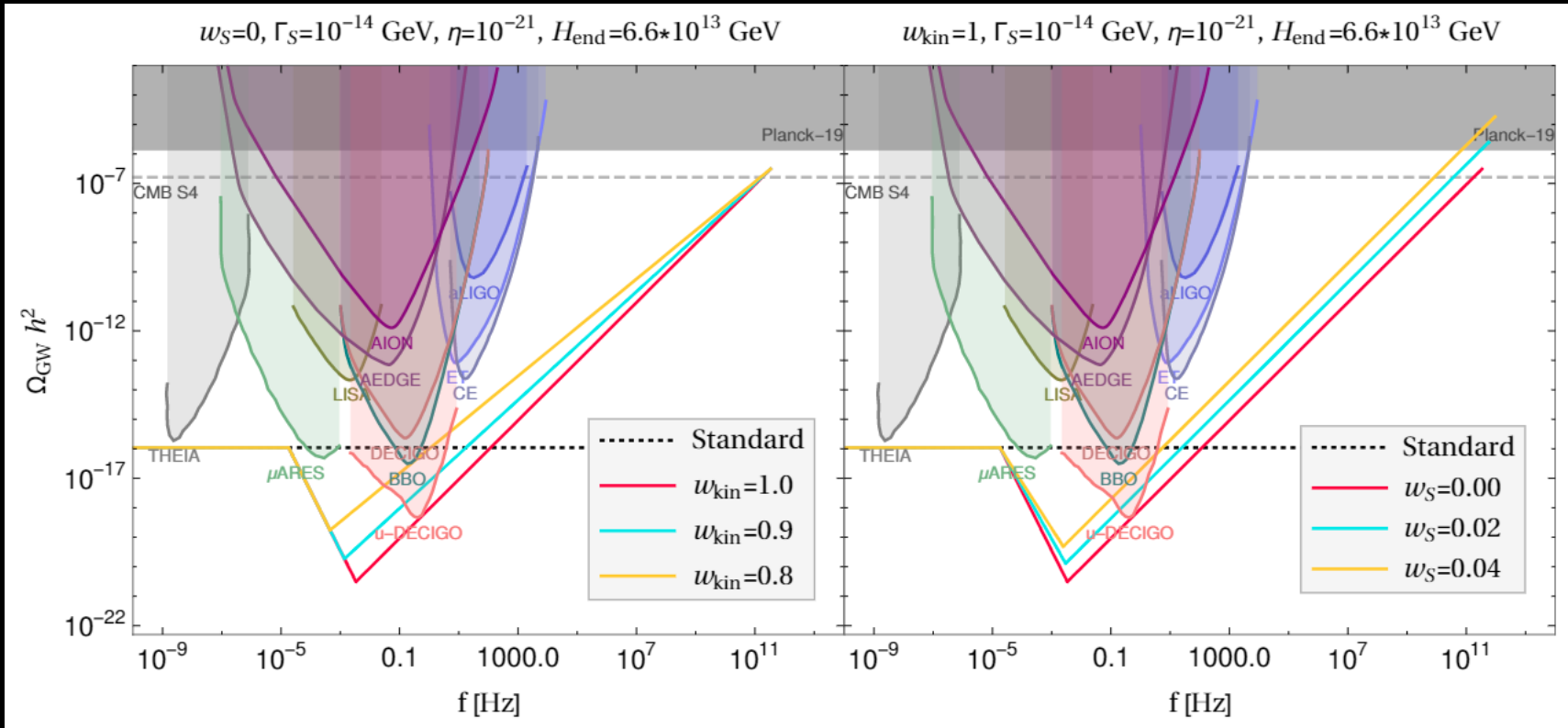
# Gravitational-wave signature

$$\frac{d\rho_{GW}}{d\log(k)} \propto a_k^{1-3w} \propto k^{-2\frac{1-3w}{1+3w}}$$

Scale-Invariant spectrum from inflation

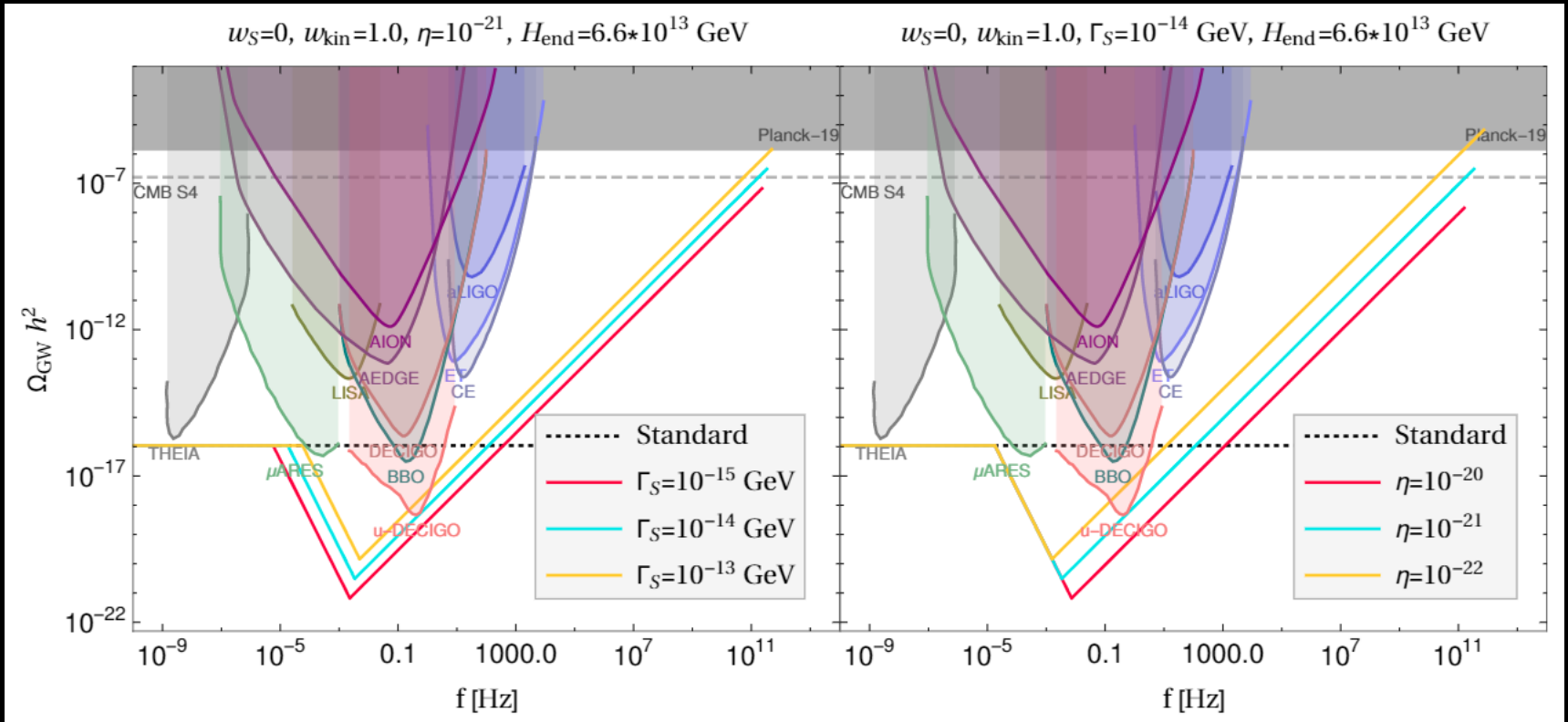

$$\Omega_{GW}^0(k) = \Omega_{GW}^{0,\text{flat}} \begin{cases} 1, & k < k_{\text{RH}}^0 \\ \left(\frac{k}{k_{\text{RH}}^0}\right)^{\frac{2(3w_S-1)}{1+3w_S}}, & k_{\text{RH}}^0 \leq k \leq k_{\text{kin}}^0 \\ \left(\frac{k_{\text{kin}}^0}{k_{\text{RH}}^0}\right)^{\frac{2(3w_S-1)}{1+3w_S}} \left(\frac{k}{k_{\text{kin}}^0}\right)^{\frac{2(3w_{\text{kin}}-1)}{1+3w_{\text{kin}}}}, & k_{\text{kin}}^0 \leq k \leq k_{\text{end}}^0 \\ 0 & k_{\text{end}}^0 < k \end{cases}$$

# Gravitational-wave signature



A. Ghoshal, LH, A. Paul [[ArXiv: 2208.01670](https://arxiv.org/abs/2208.01670)]

# Gravitational-wave signature

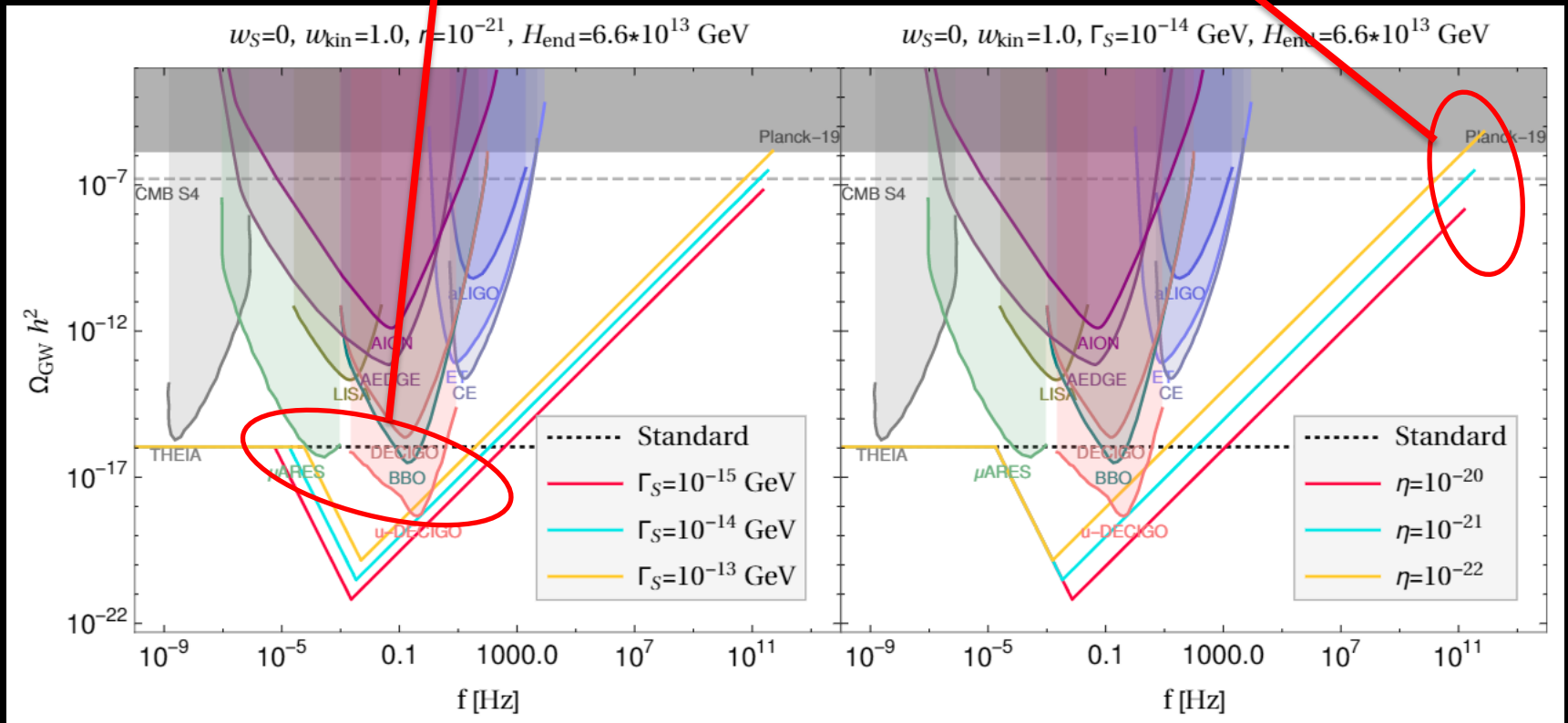


A. Ghoshal, LH, A. Paul [[ArXiv: 2208.01670](https://arxiv.org/abs/2208.01670)]

# Gravitational-wave signature

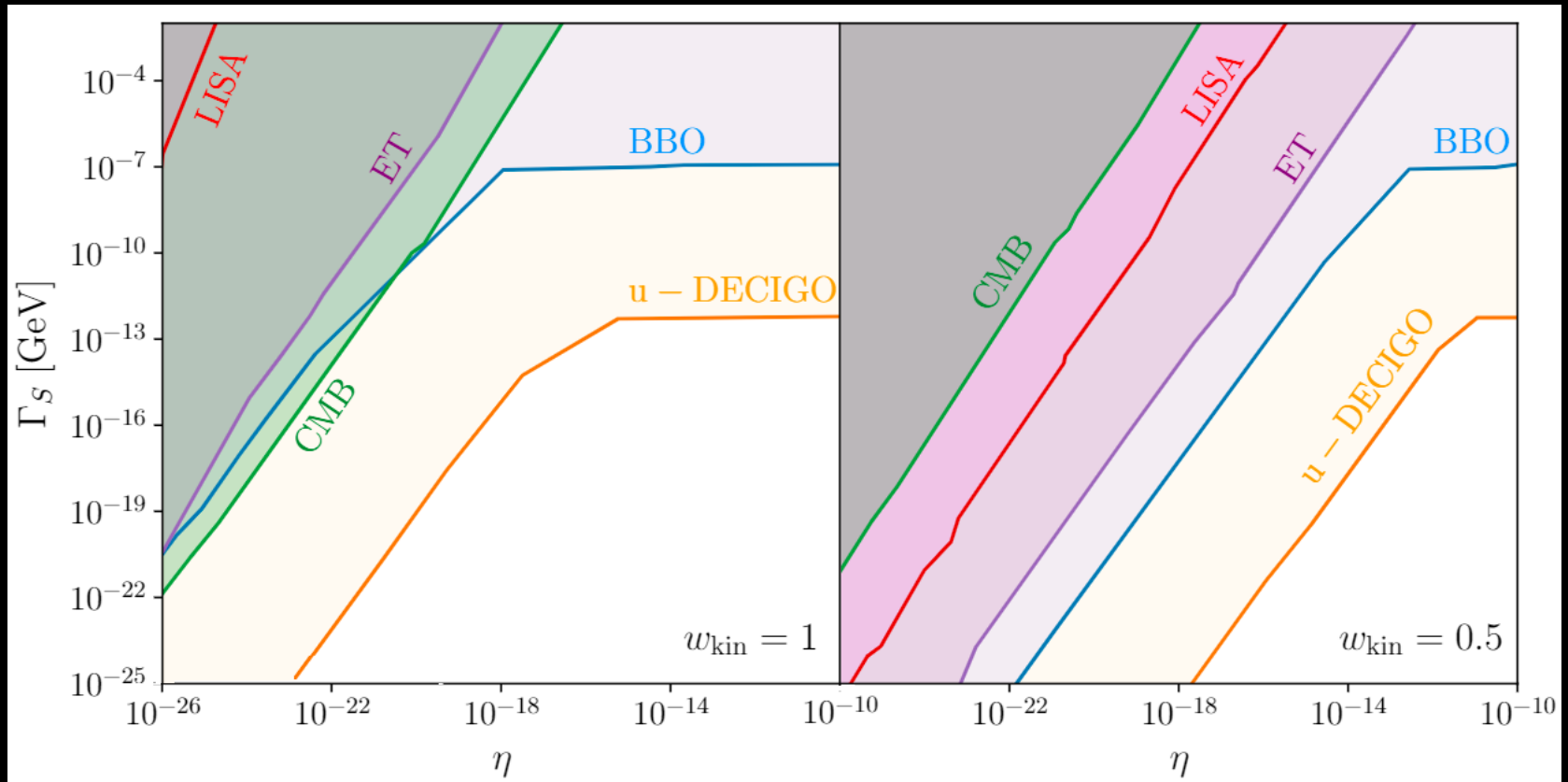
GW detection

Contribution to  $\Delta N_{\text{eff}}$



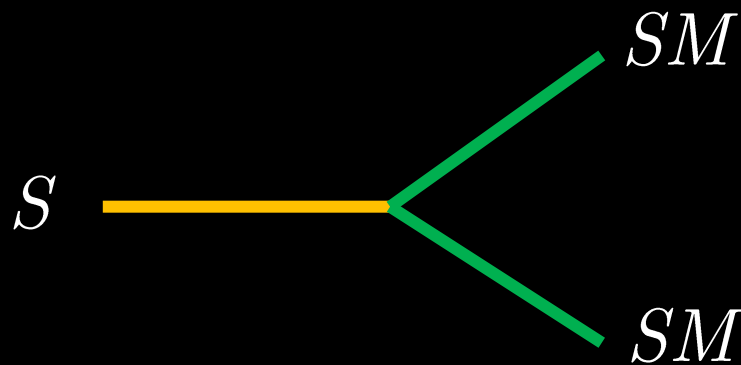
A. Ghoshal, LH, A. Paul [[ArXiv: 2208.01670](https://arxiv.org/abs/2208.01670)]

# Gravitational-wave signature

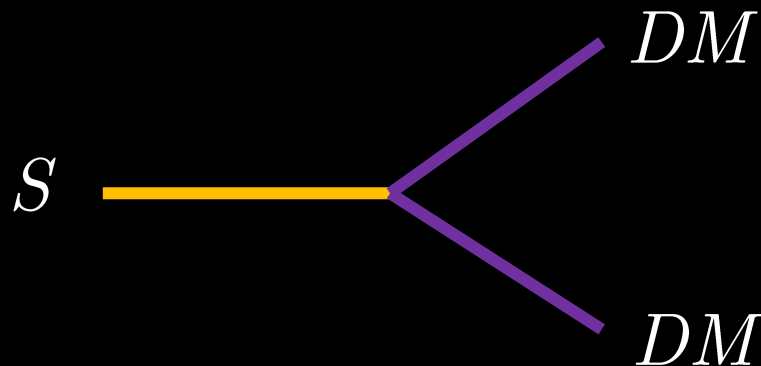


A. Ghoshal, LH, A. Paul [[ArXiv: 2208.01670](https://arxiv.org/abs/2208.01670)]

# Laboratory Searches



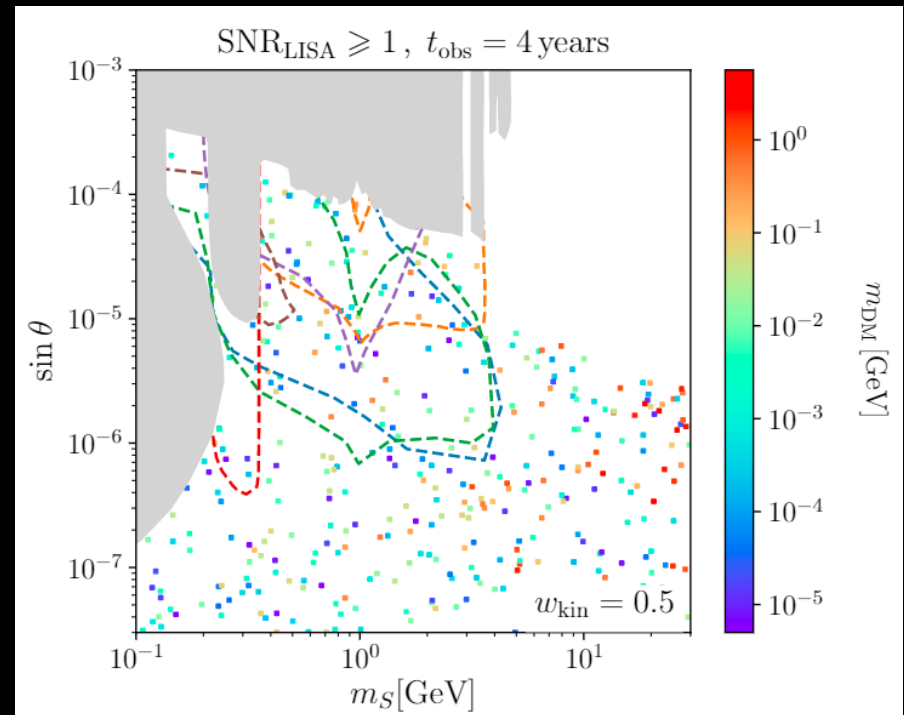
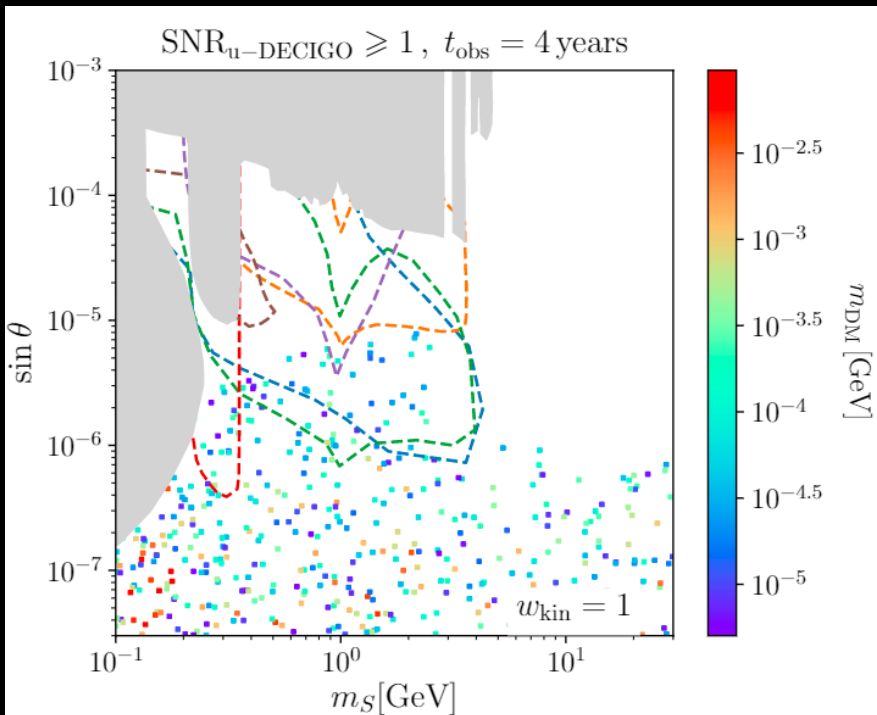
$S$  can be looked for in long-lived particle searches



$DM$  could be produced through Freeze-In via exchange of  $S$

# Laboratory Searches

- **FASER, DUNE, DARKQUEST2, MATHUSLA, PS191, and SHIP**



A. Ghoshal, LH, A. Paul [[ArXiv: 2208.01670](https://arxiv.org/abs/2208.01670)]



# CONCLUSION

- Models with modified post-inflationary cosmology can lead to observable gravitational wave signals
- Non-oscillatory inflation needs a mechanism to transfer energy to the SM: may lead to periods of kination and early matter domination
- The reheating mechanism can be probed by long-lived particle searches leading
- Laboratory experiments and gravitational wave searches can act as complementary ways to probe early cosmology
- Post-Inflationary signatures may help making predictions for the CMB more accurate...

Back up