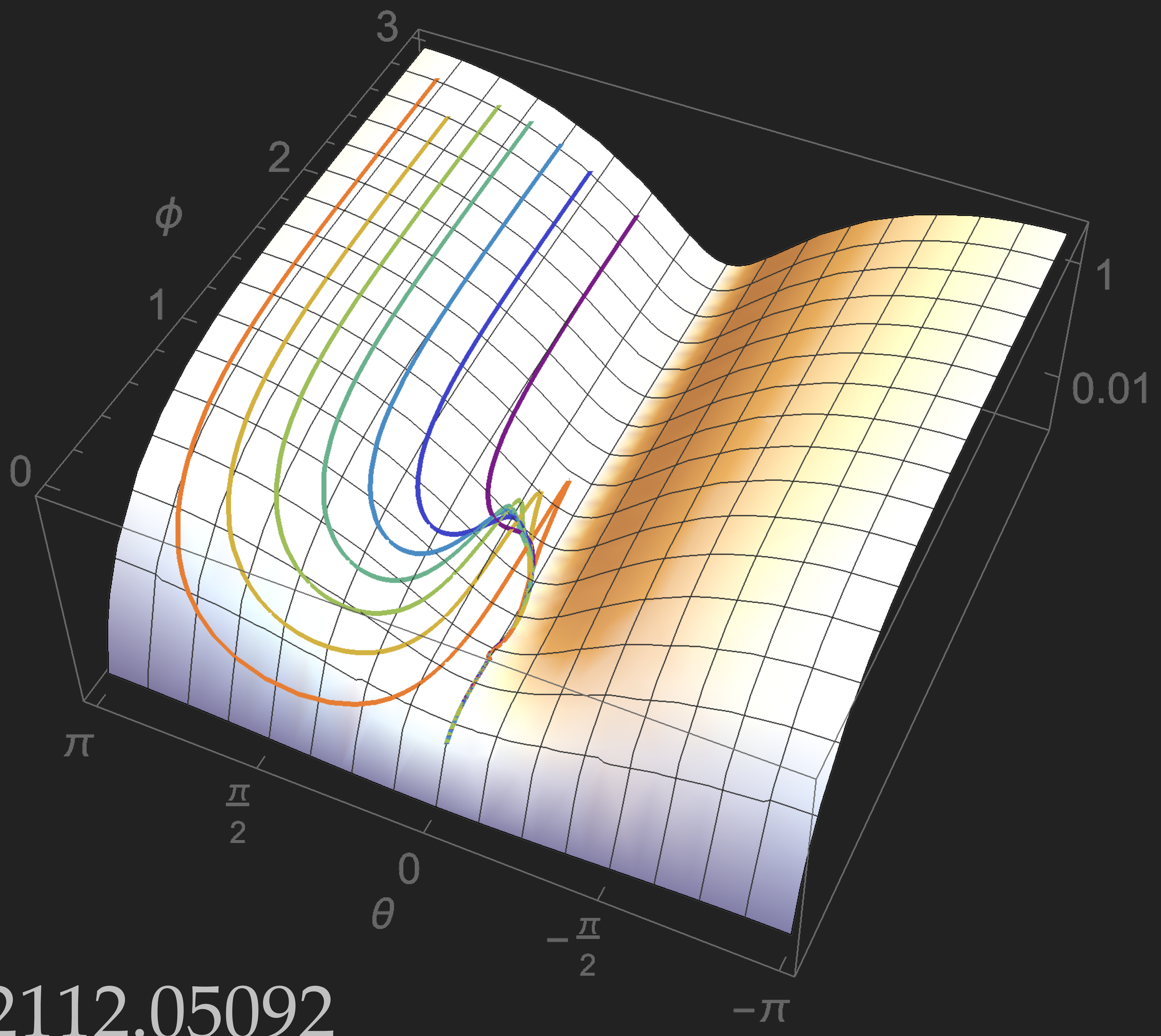
Small-Scale Tests of Inflation

Laura Iacconi (Queen Mary University of London)

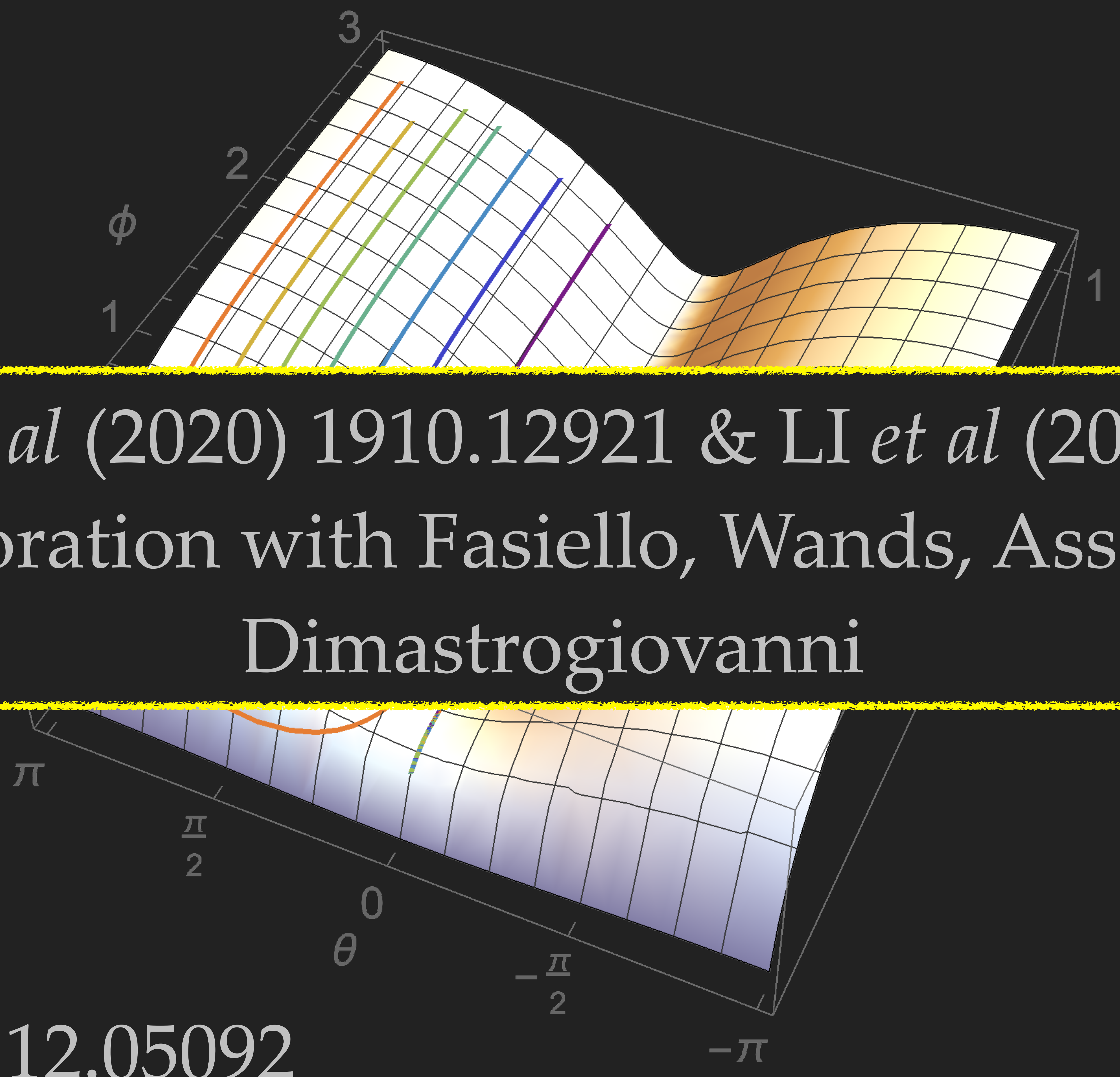
PNG Conference @ IFT, Madrid, Sept 23rd 2022

Revisiting small-scale fluctuations in α-attractors



LI *et al* (2022) 2112.05092

Revisiting small-scale fluctuations in α-attractors

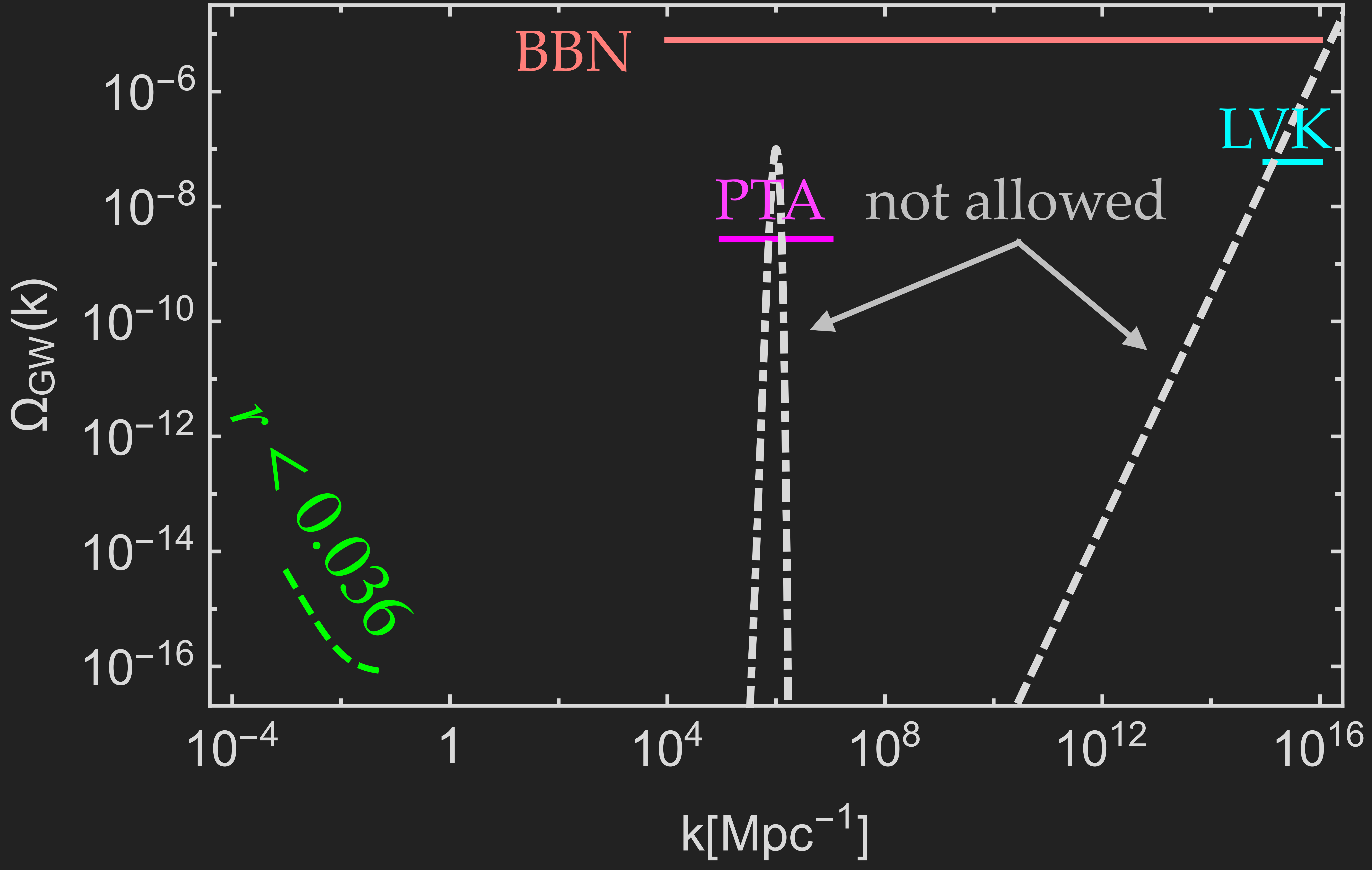


Based on: LI *et al* (2020) 1910.12921 & LI *et al* (2020) 2008.00452 in collaboration with Fasiello, Wands, Assadullahi & Dimastrogiovanni

LI *et al* (2022) 2112.05092

Current experimental bounds on primordial GWs

$$\Omega_{GW}(k) \equiv \frac{1}{12}\left(\frac{k}{a_0 H_0}\right)^2 P_\gamma(k)\, T(k)^2$$



Single-field slow-roll primordial GWs

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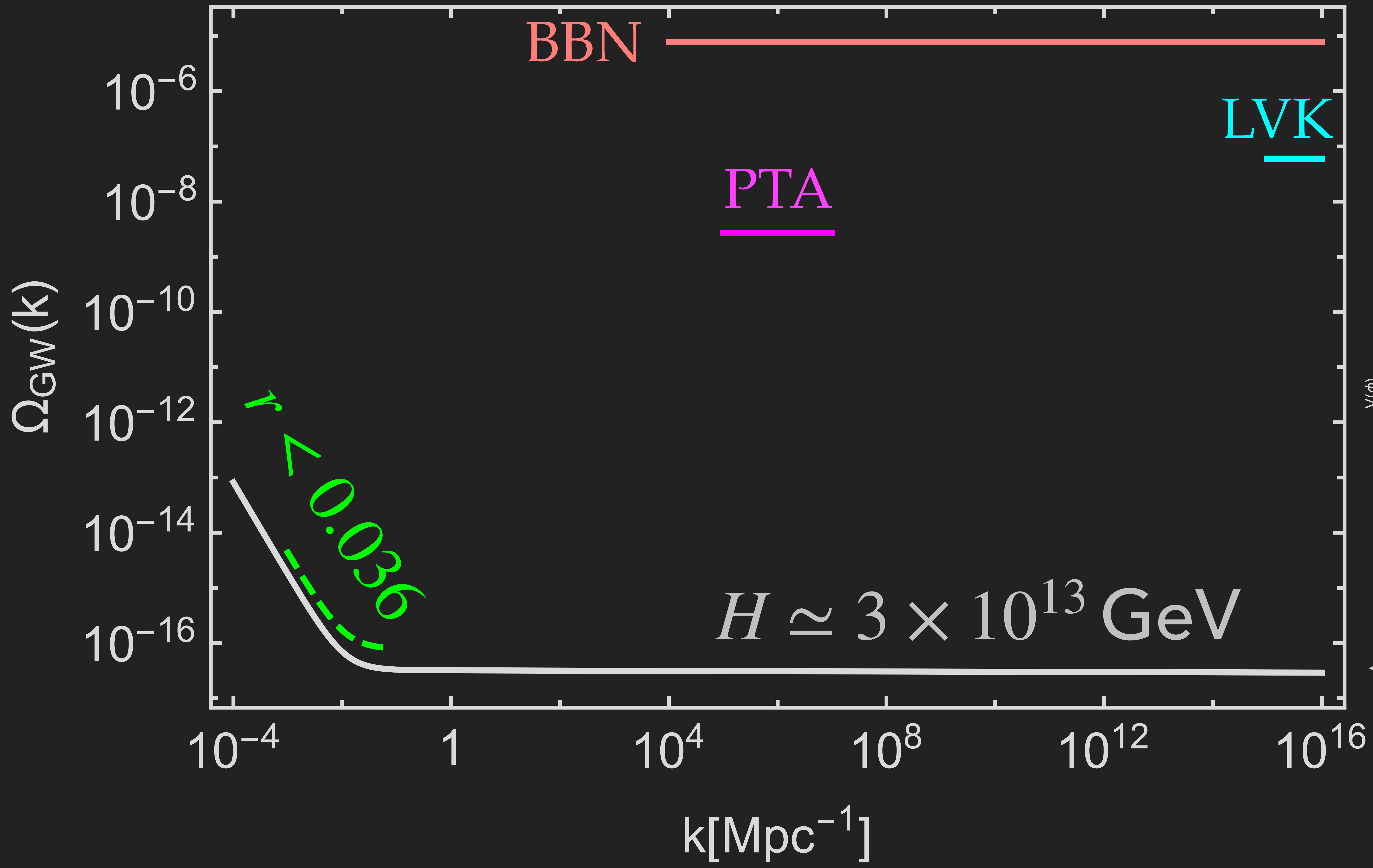
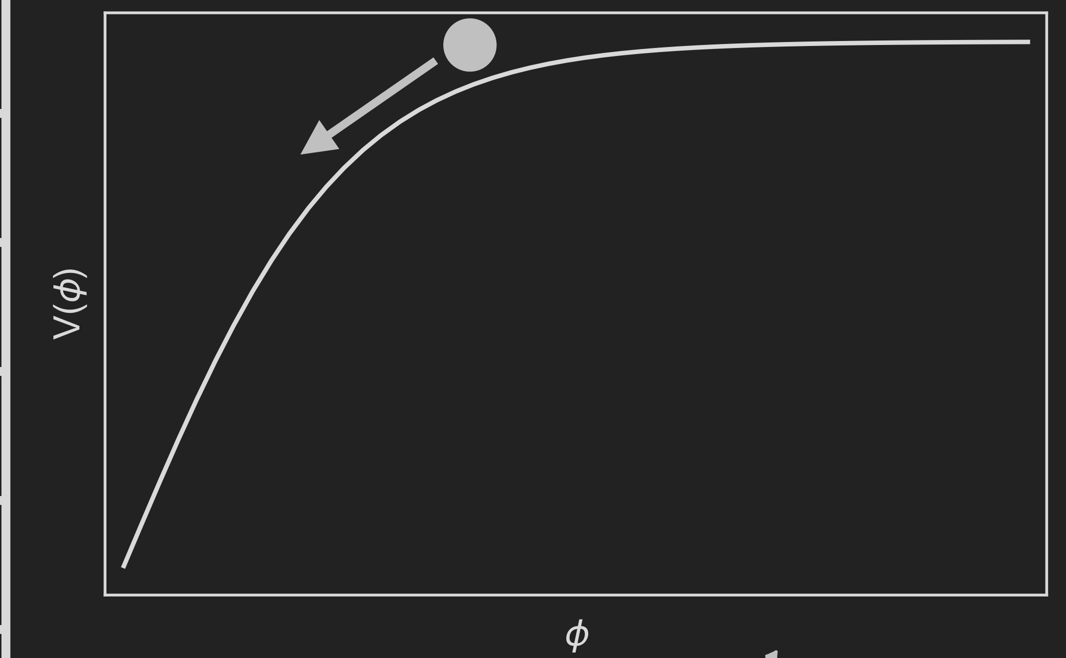
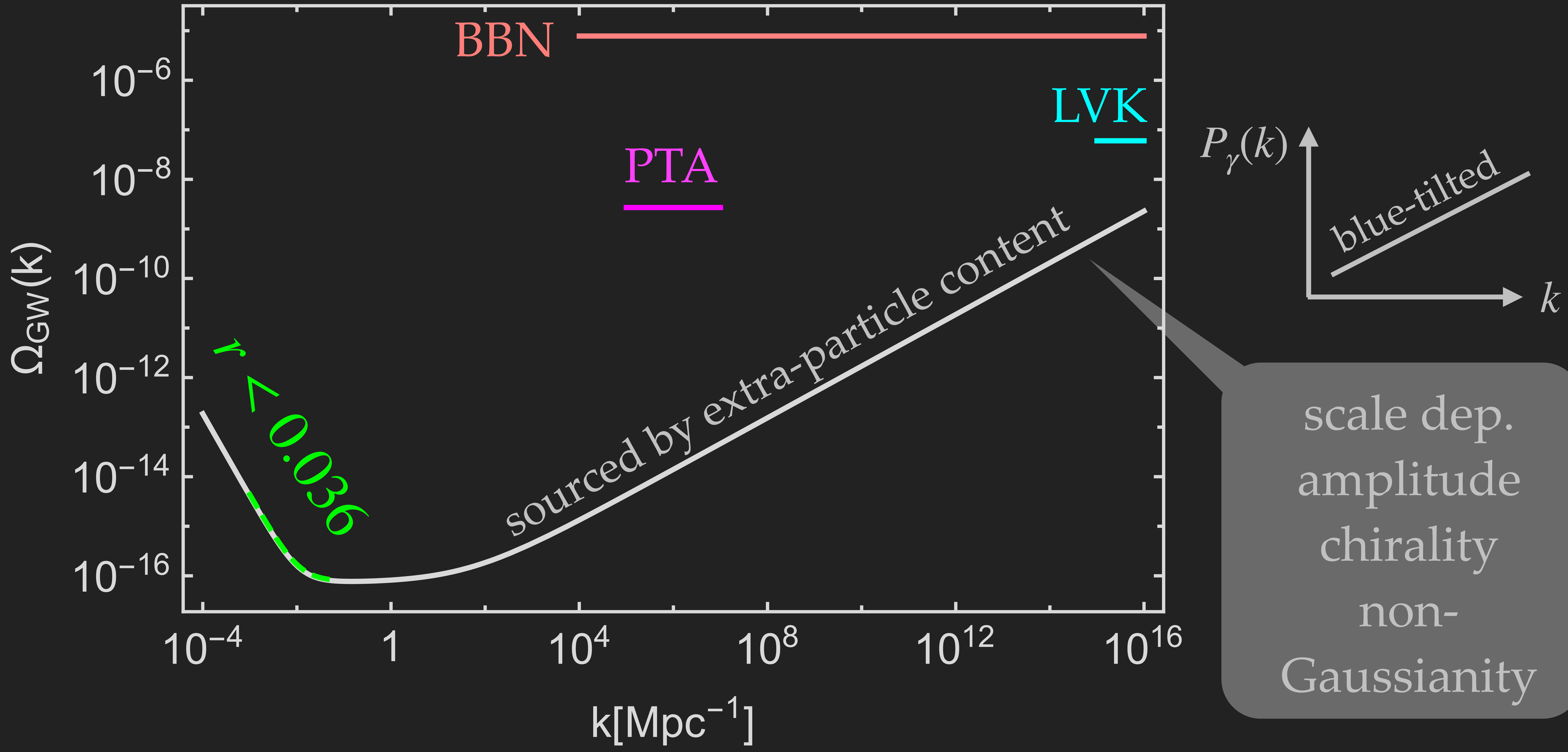




quantum vacuum fluctuations of metric

Beyond SF inflation: non-minimal inflationary field content

$$\Omega_{GW}(k) \equiv \frac{1}{12}\left(\frac{k}{a_0 H_0}\right)^2 P_\gamma(k)\, T(k)^2 \quad \text{with} \quad P_\gamma = P_{\gamma,vac} + P_{\gamma,source}$$



scale dep.
amplitude
chirality
non-Gaussianity

Beyond SF inflation: non-minimal inflationary field content

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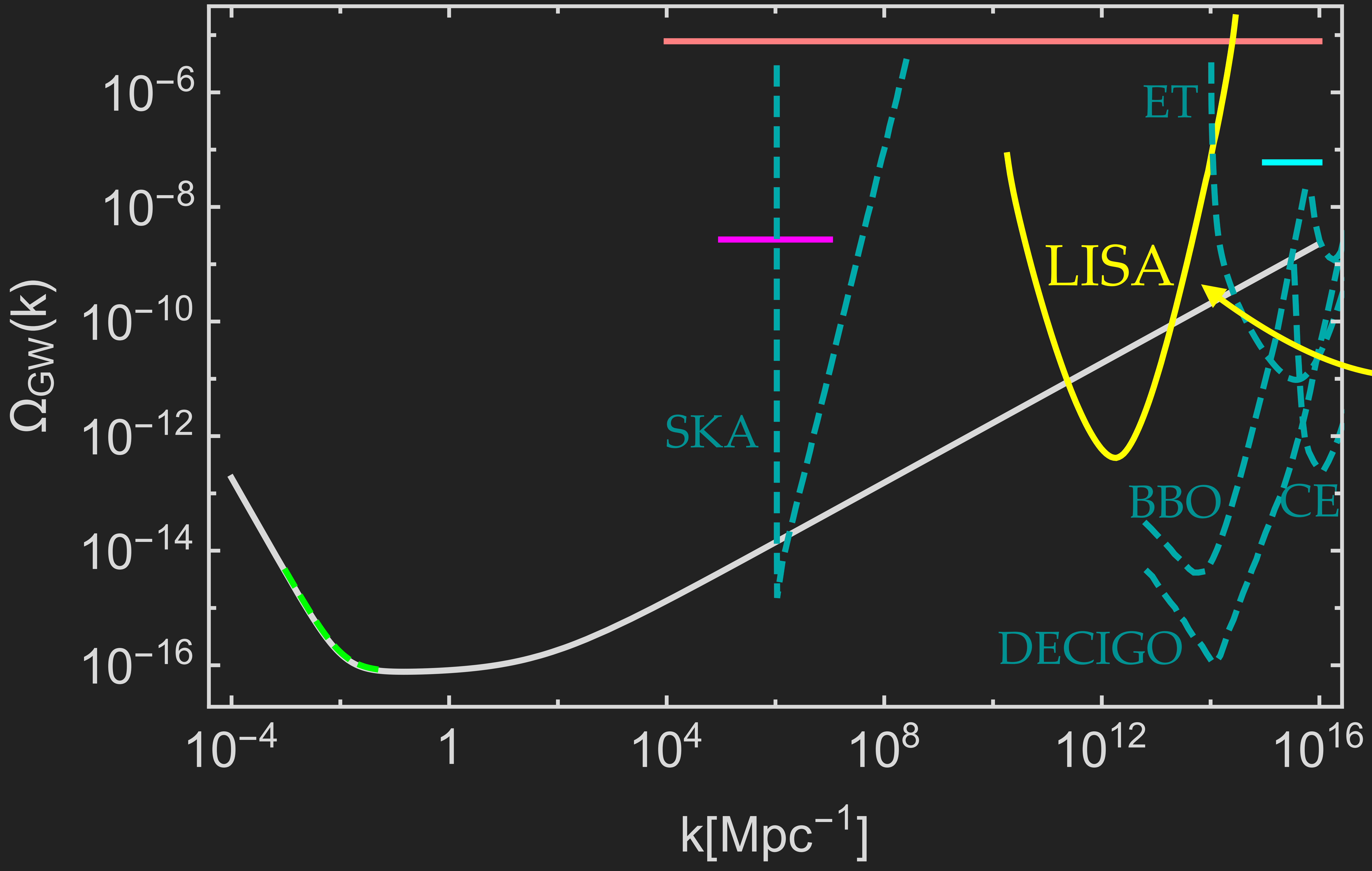
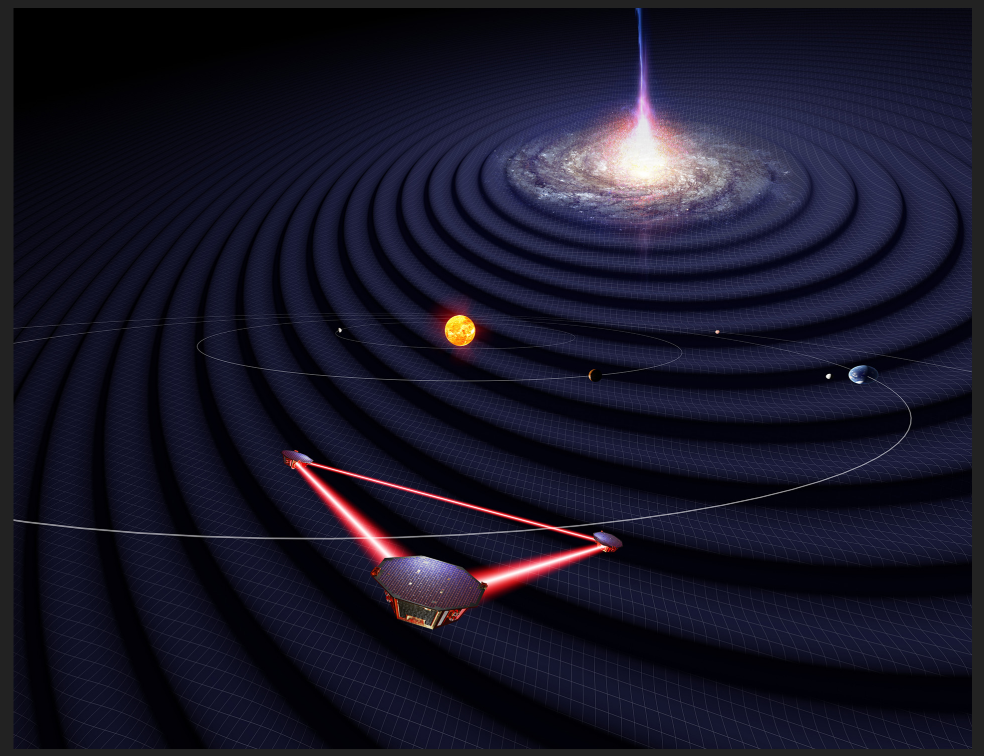




EFT of spinning particles in inflation

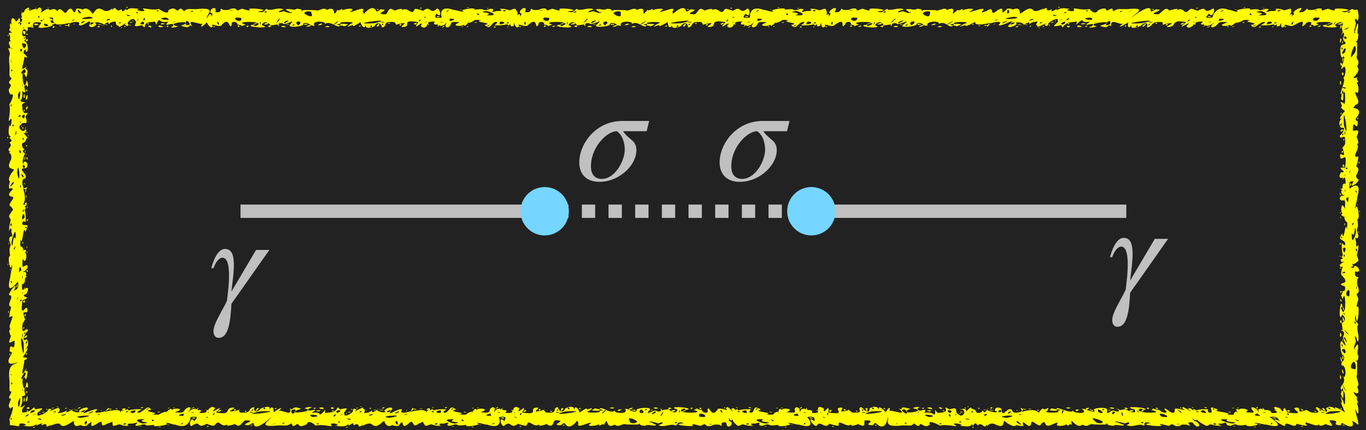
- on quasi de Sitter space, a non-minimal coupling with the inflaton makes the spin-2 effectively lighter $(m \ll H)$

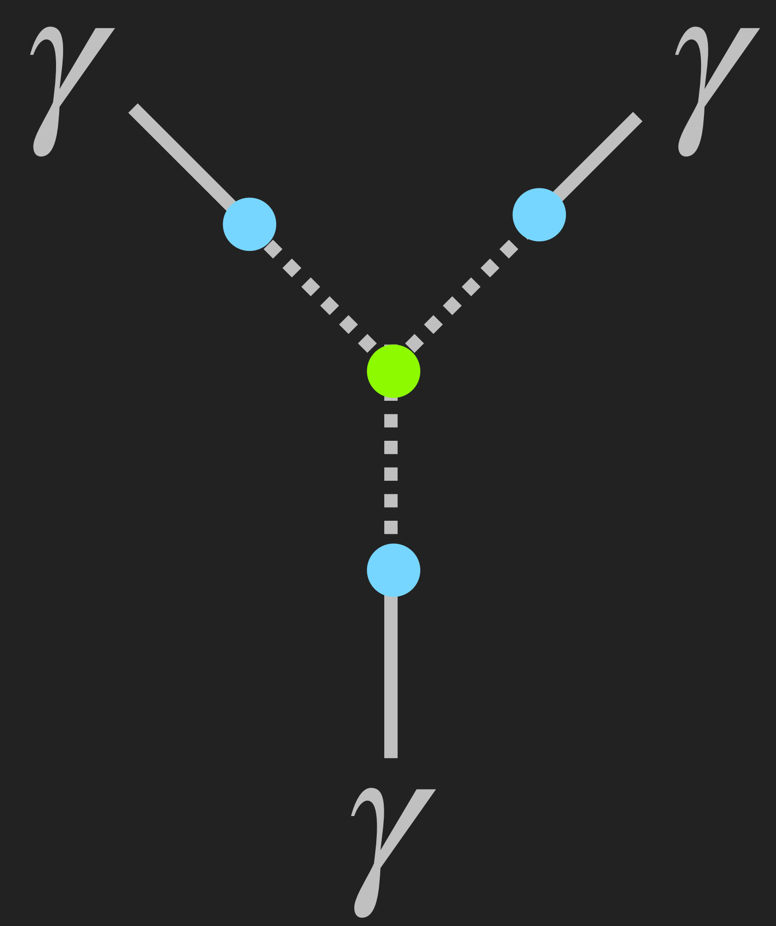
Bordin *et al* (2020) 1806.10587

- action for the tensor sector:

$$\mathscr{L}^{(2)} \supseteq a^3 \frac{1}{2} \rho \dot{\gamma}_{c\,ij} \sigma^{ij}$$

$$\mathscr{L}^{(3)} = -a^3 \mu (\sigma_{ij})^3$$





spin-2: $\sigma_{ij}(\bar{x}, t)$

tensor: $\gamma_{ij}(\bar{x}, t)$

LI *et al* (2020) 1910.12921

LI *et al* (2020) 2008.00452

Sourced primordial GWs

$$P_\gamma = \underbrace{\frac{2H^2}{\pi^2 M_p^2}}_{\text{vacuum}} + \underbrace{\frac{2H^2}{\pi^2 M_p^2}\frac{C_\gamma(\nu)}{c_2^{2\nu}}\left(\frac{\rho}{H}\right)^2}_{\text{source}}$$

spin-2 mass, $\nu = \sqrt{\frac{9}{4} - \left(\frac{m}{H}\right)^2}$

helicity-2 sound speed c_2

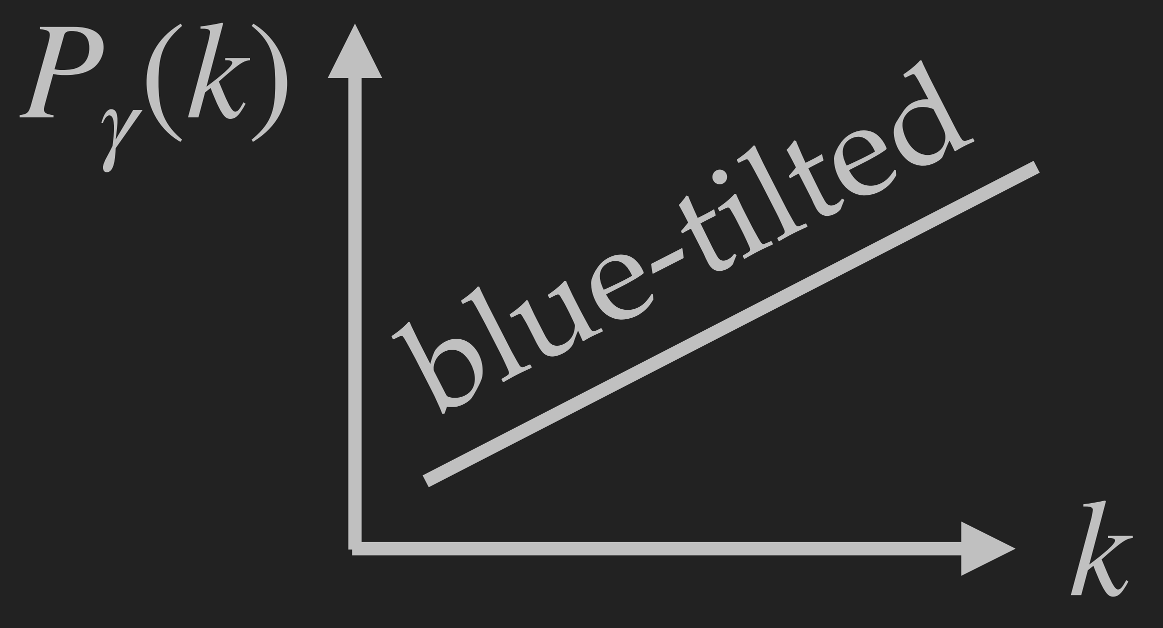
coupling $\frac{\rho}{H}$

- Our set-up: *time-dependent* sound speeds $\{c_0, c_1, c_2\}$, $s_i = \frac{\dot{c}_i}{H c_i}$
  {Bartolo *et al* (2016), 1610.06481}

see Ana's talk

$$P_\gamma(k) \propto \frac{1}{c_2^{2\nu}} \to \frac{1}{c_2^{2\nu}}\left(\frac{k}{k_\star}\right)^{-2\nu s_2}$$

if $s_2 < 0$

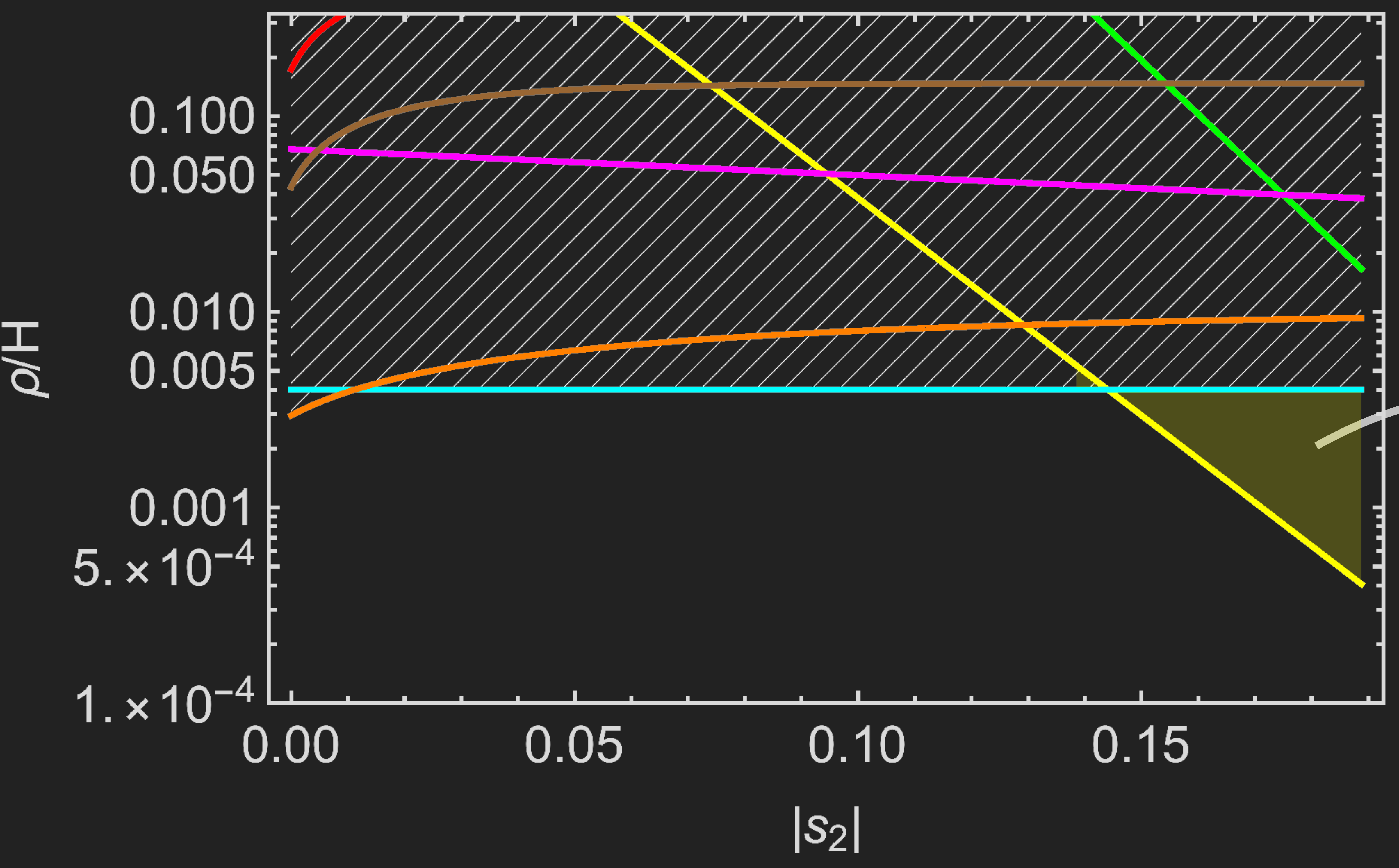


Example of our analysis

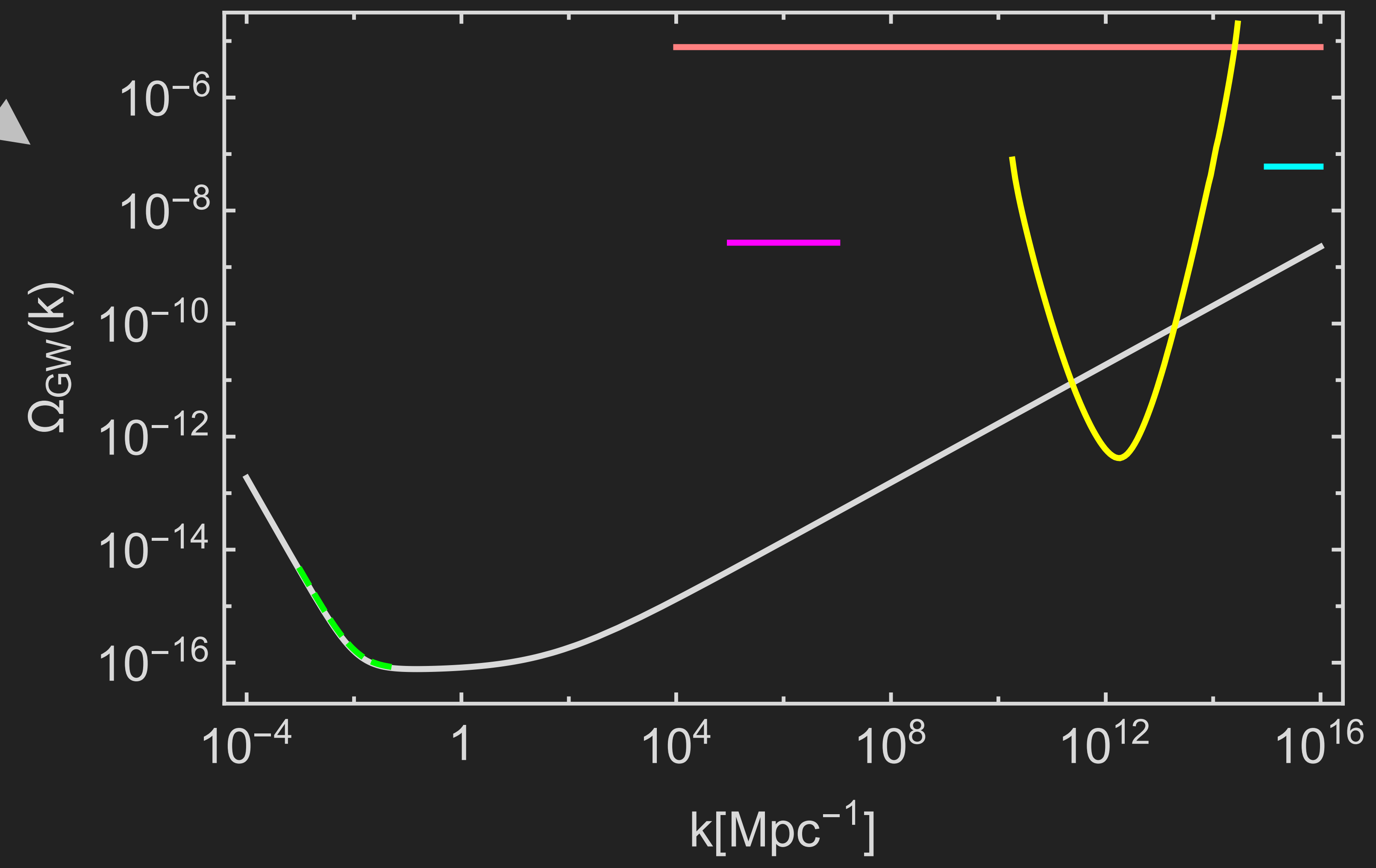
$$\left\{H = 4.5\mathrm{x}10^{13}\,\mathrm{GeV}\;,\; \frac{m}{H} = 0.54\;,\; c_{2\,in} = 1\;,\; c_1 = 0.55\;,\; \frac{\rho}{H}\;,\; s_2\right\}$$

fix these

parameter space



CMB, PBHs, LIGO,
UCMHs,
theoretical requirements,..



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fix these

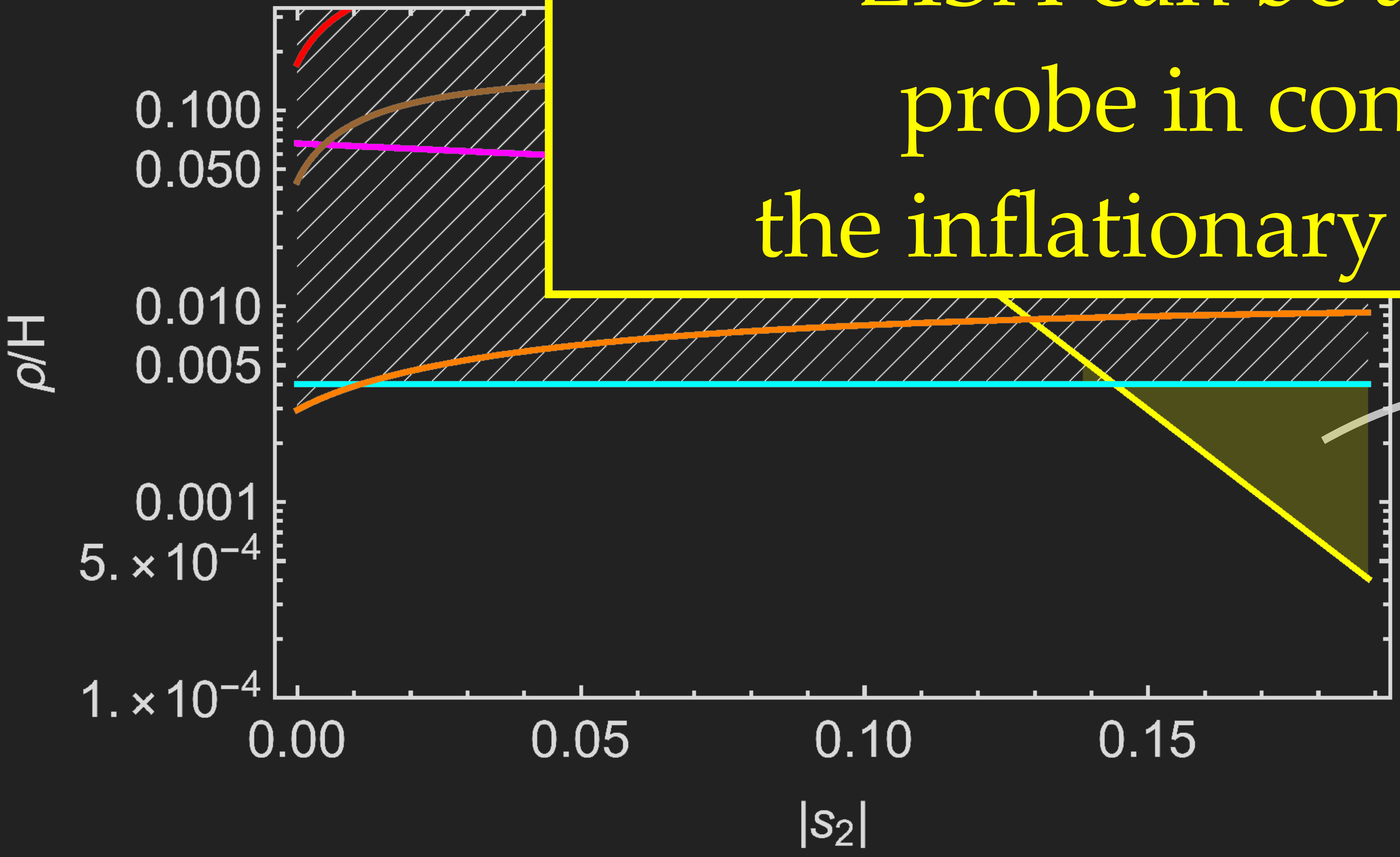
parameter space

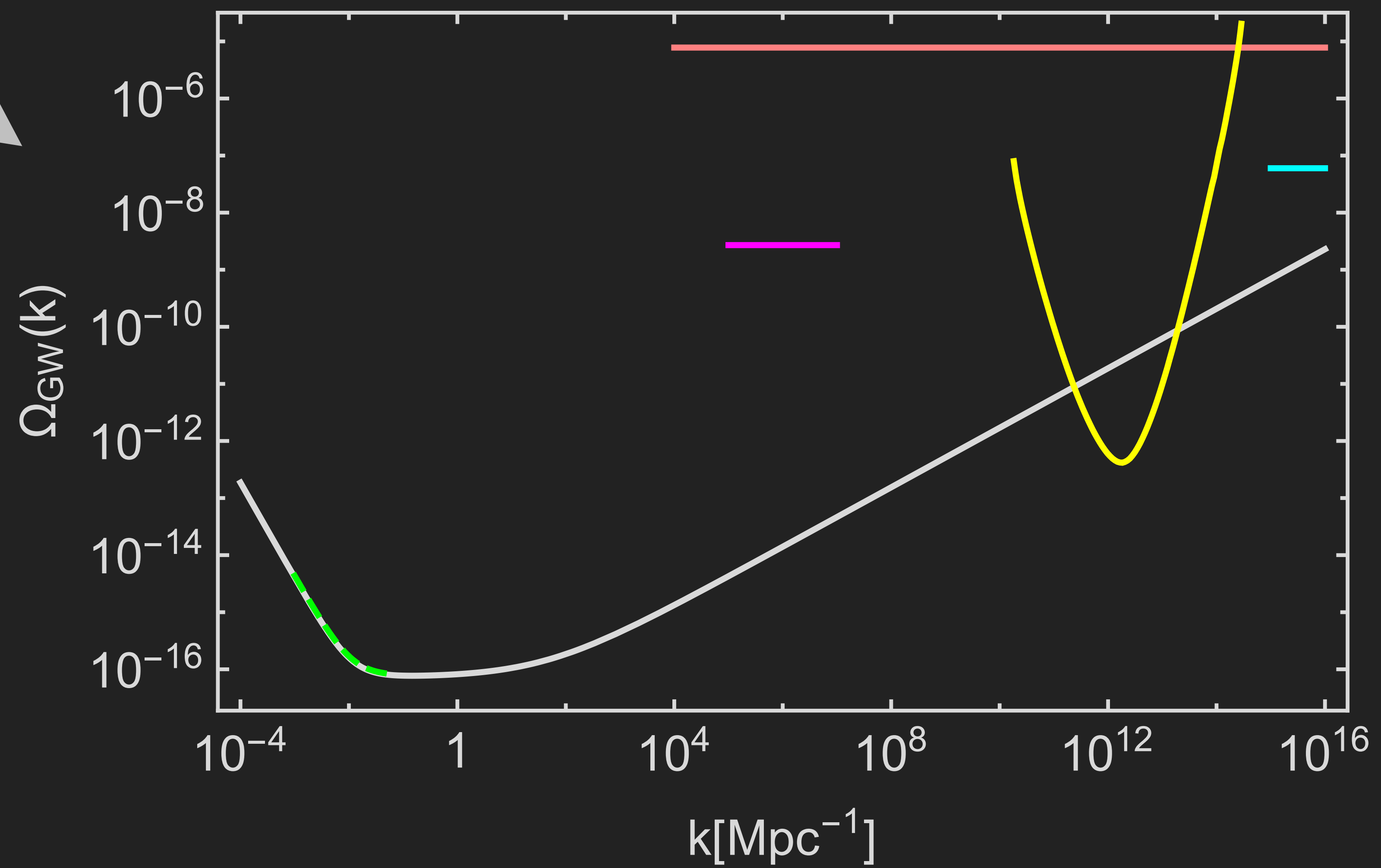
LIGO,

s,

theoretical requirements,..

LISA can be an efficient probe in constraining the inflationary field content



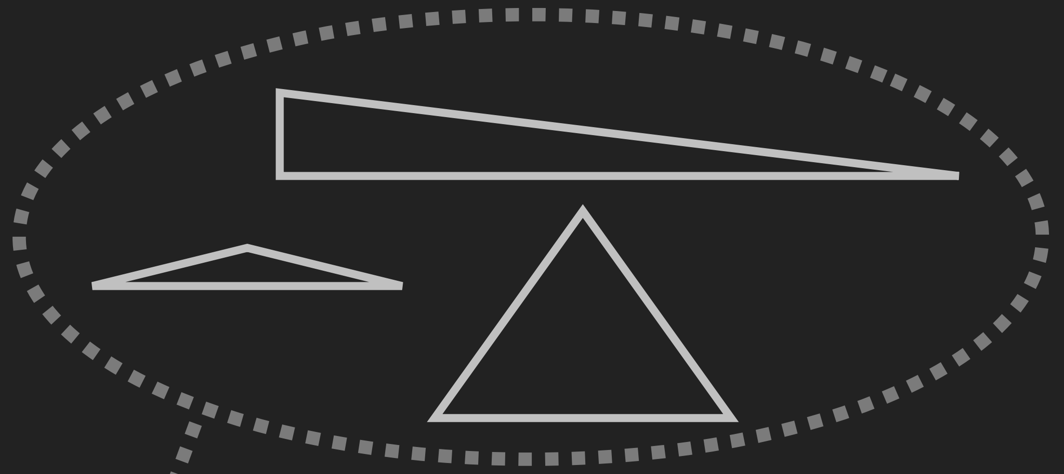


Tensor non-Gaussianities

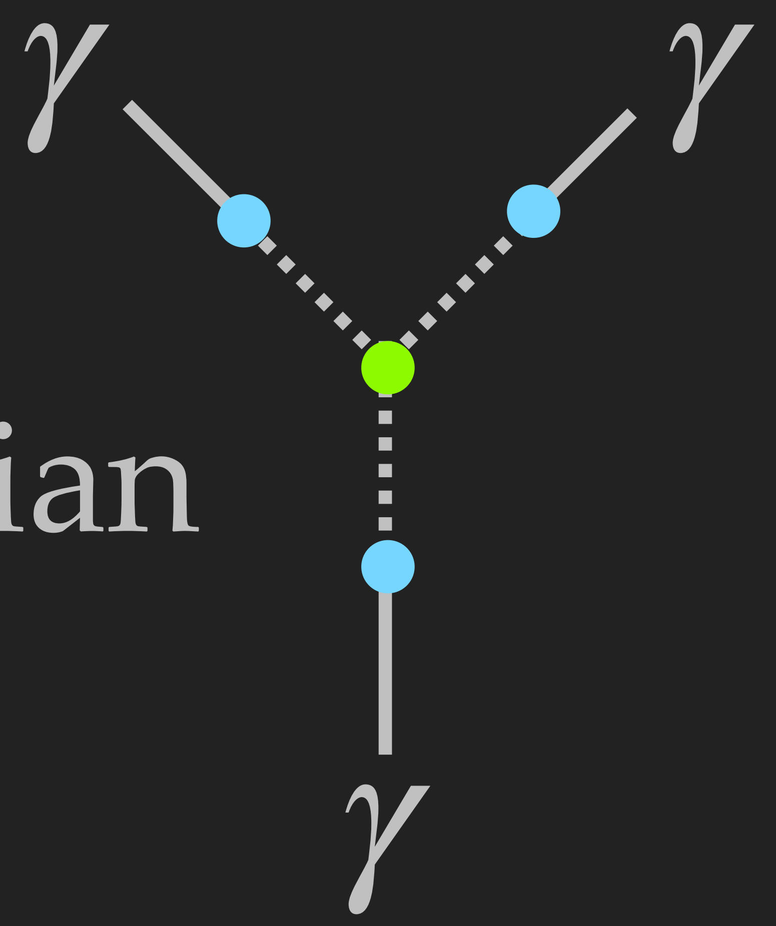
see Ameek's talk for $\langle \zeta\gamma\gamma \rangle$

$$\langle \gamma^{\lambda_1}_{\mathbf{k}_1} \gamma^{\lambda_2}_{\mathbf{k}_2} \gamma^{\lambda_3}_{\mathbf{k}_3} \rangle = (2\pi)^3\, \delta^{(3)}(\mathbf{k}_1 + \mathbf{k}_2 + \mathbf{k}_3)\, \mathscr{A}^{\lambda_1\lambda_2\lambda_3}\, B_\gamma(k_1, k_2, k_3)$$

$$f_{NL} = \frac{B}{P_\gamma^2}$$

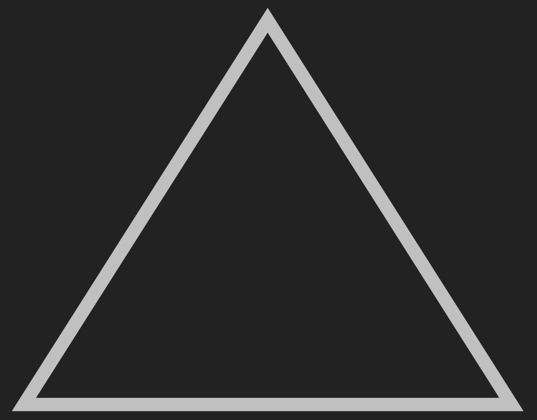


- characterised in terms of amplitude and shape
- source of a wealth of information about the Lagrangian
- what is the effect of $c_2(k) = c_{2\,in}\left(k/a_0H_0\right)^{s_2}$?



constant $c_2 \leq 1$: {Dimastrogiovanni *et al* (2019) 1810.08866}

Equilateral configuration



$$k_1 \sim k_2 \sim k_3 \sim k$$

Squeezed configuration

$$k_3 \sim k_L \ll k_1 \sim k_2 \sim k_S$$

We find that:

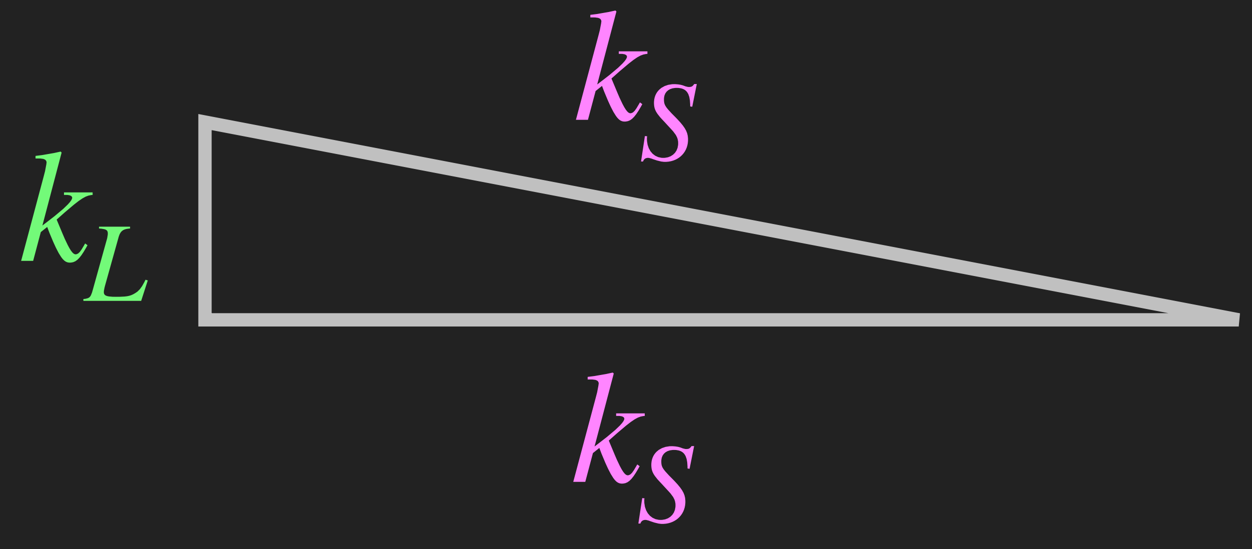
- shape interpolates between local and equilateral configs depending on spin-2 mass
- the lighter the spin-2, the greater the signal
- decreasing c_2 -> sizeable amplitude on small scales

Testing the tensor bispectrum

see Ameek's talk

- not directly detectable by interferometers on small scales {Bartolo *et al* (2019) 1810.2218}
- if there is a non-trivial squeezed bispectrum, the long wavelength mode k_L induces a quadrupolar anisotropy in the short modes

$P_\gamma(k_S)$

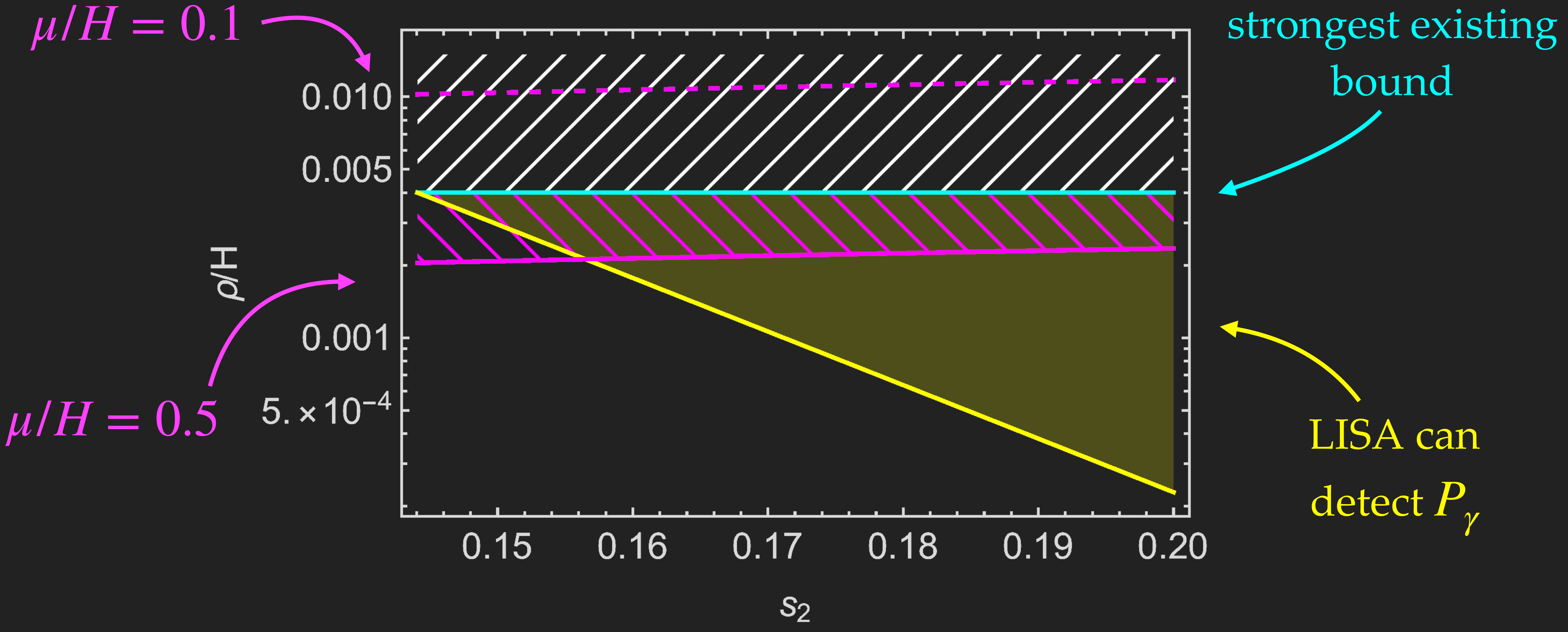


$$P_\gamma(\mathbf{k_S}) = P_\gamma(k_S)\left(1 + \mathcal{Q}_{lm}(\mathbf{k_S})\hat{k}_{S_l}\hat{k}_{S_m}\right)$$

$$\mathcal{Q}_{lm}(\mathbf{k_S}) \propto \int f_{NL}(k_L, k_S)$$

{Dimastrogiovanni *et al* (2020) 1906.07204}

Testing the (squeezed) tensor bispectrum



Conclusions

- Primordial GWs can be an excellent probe of primordial physics + carry info on extra particle content during inflation
- Non-minimal couplings enhance the effects of massive spinning fields at small scales
- Time-dependent c_2 can deliver detectable signal at small scales
- Squeezed Bispectrum mediated by spin-2 fields testable at small scales (multi-proble analysis including SKA)

LI *et al* (2020) 1910.12921
LI *et al* (2020) 2008.00452

Obrigada!