Primordial Clocks in Stochastic Gravitational Wave Anisotropies

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arXiv: appears tonight!

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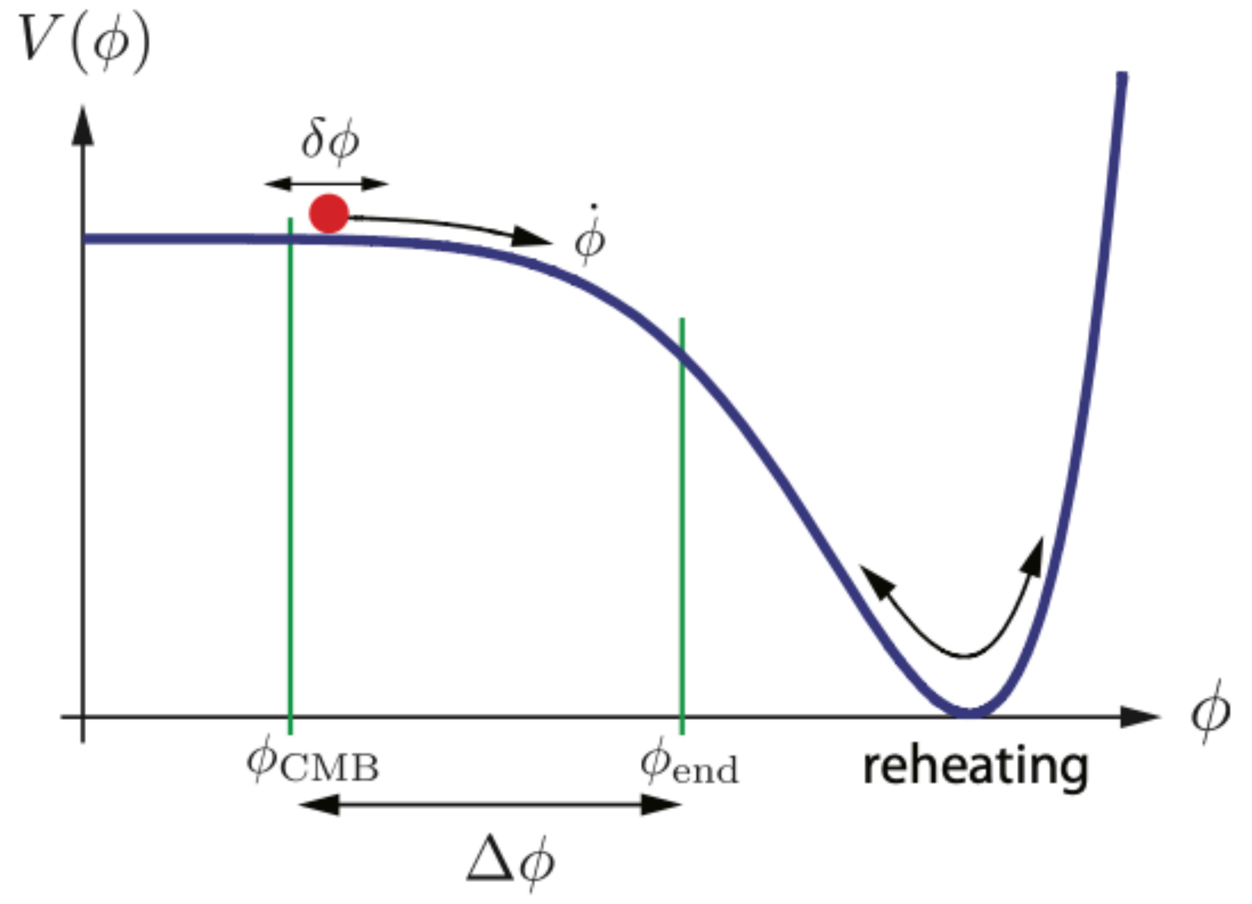
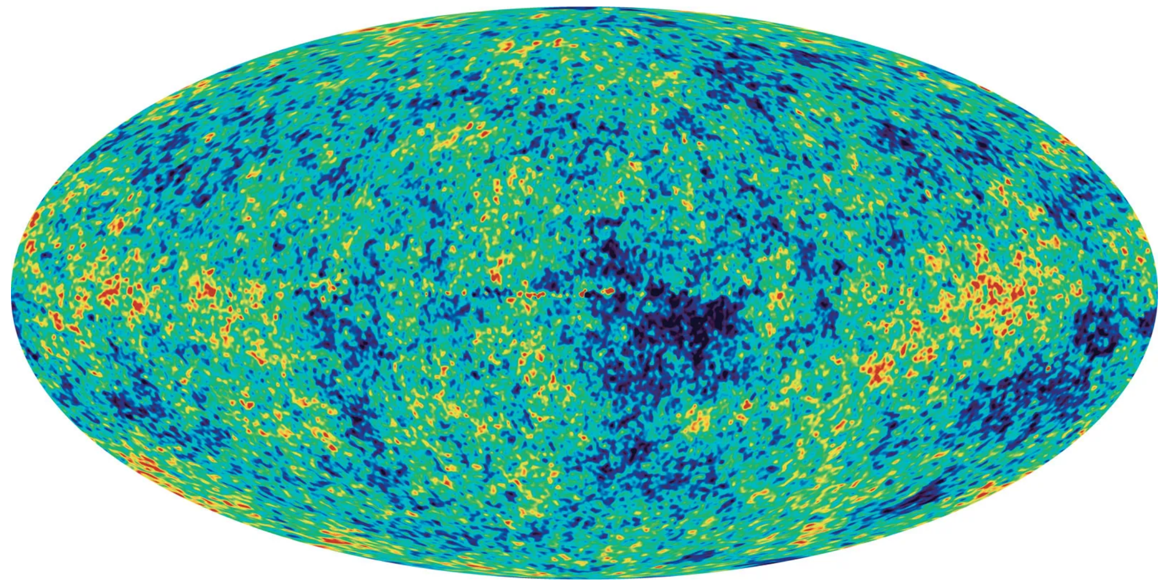
Inflation links anisotropies of late-time observables to the quantum fluctuations of inflaton field





$$\langle \delta\phi_1\, \delta\phi_2\, \cdots\, \delta\phi_n \rangle \longleftrightarrow \langle \delta T(\hat{n}_1)\, \delta T(\hat{n}_2)\, \cdots\, \delta T(\hat{n}_n) \rangle$$

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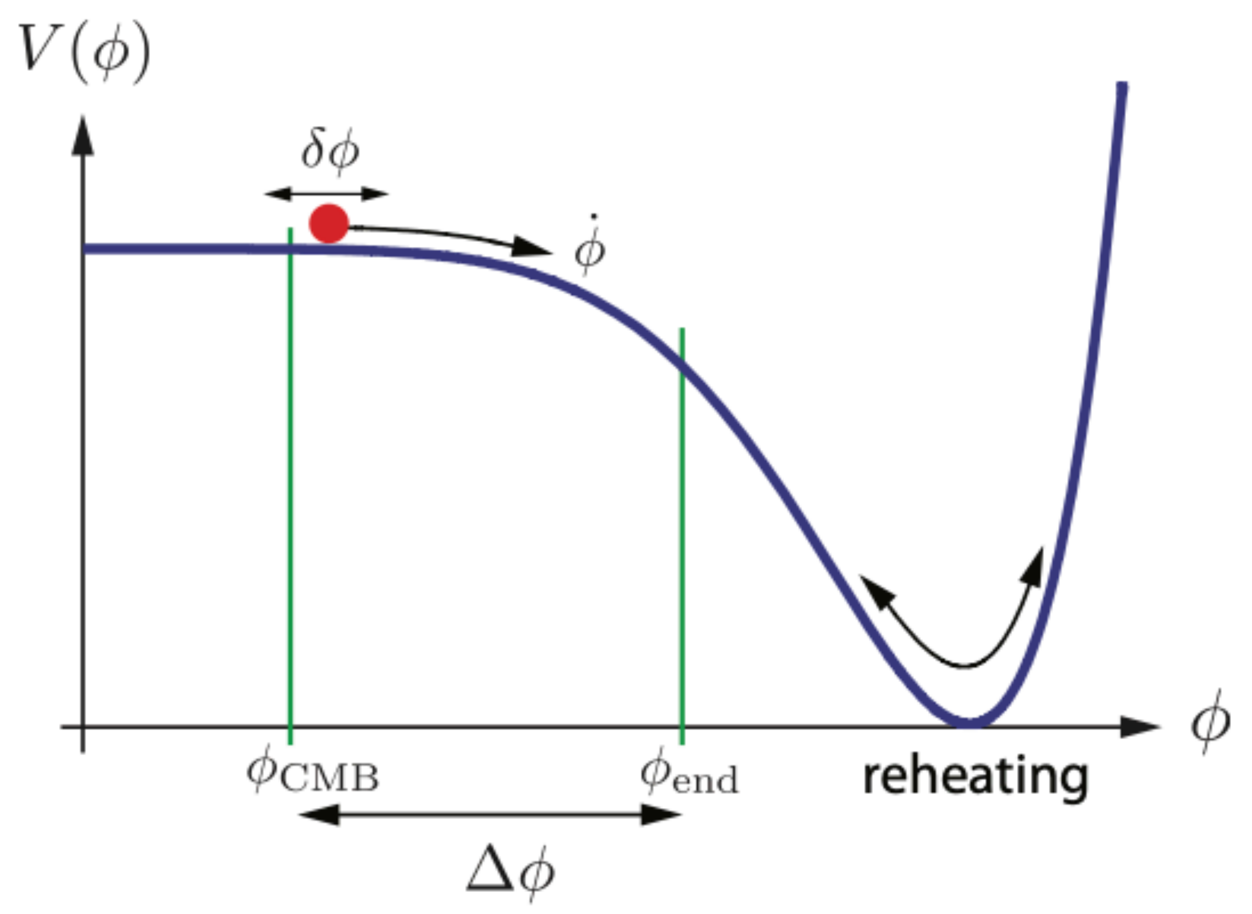

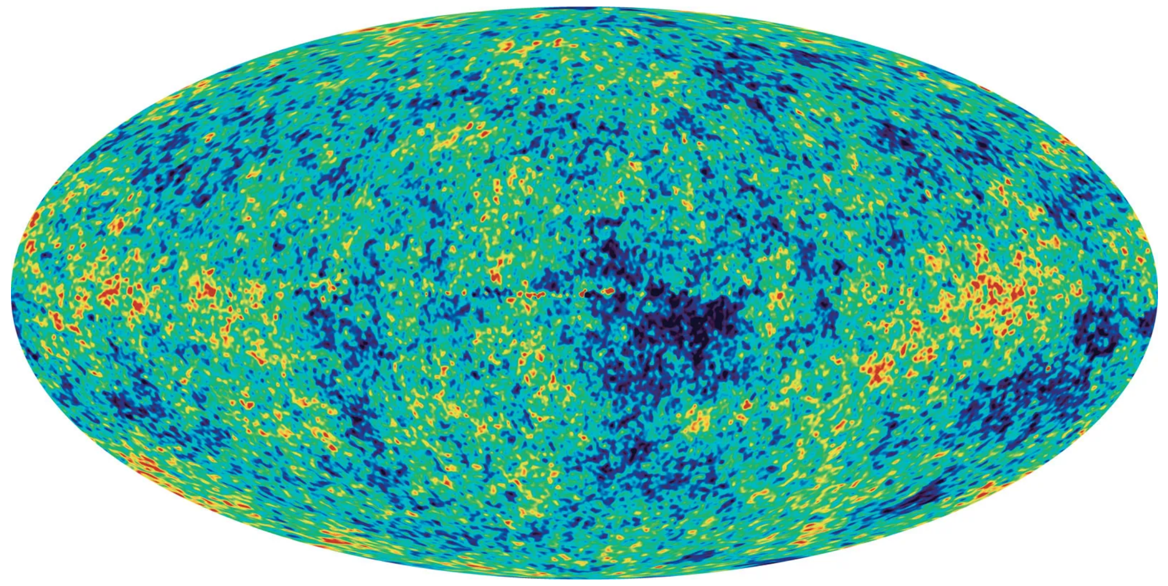

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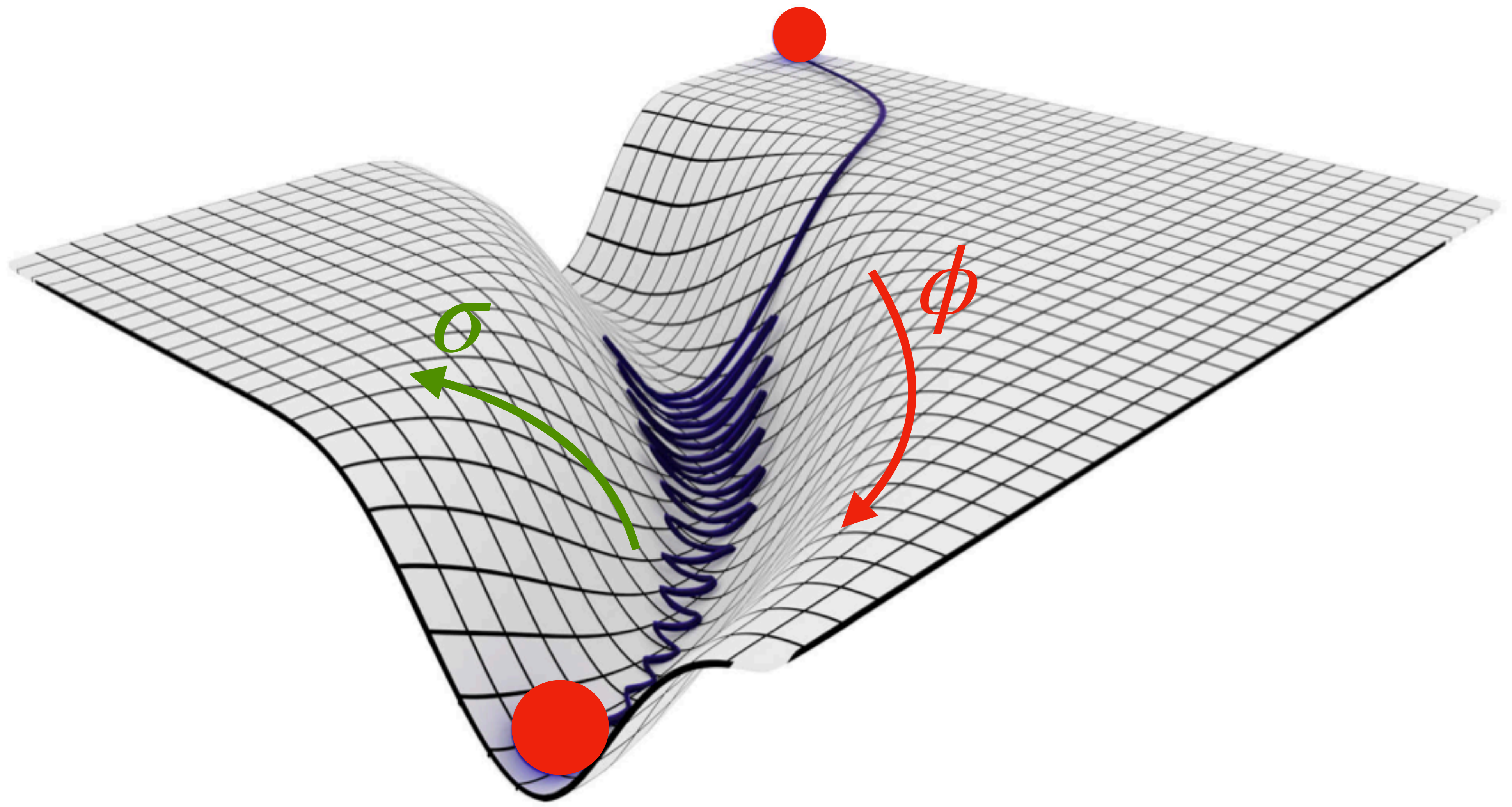
New physics

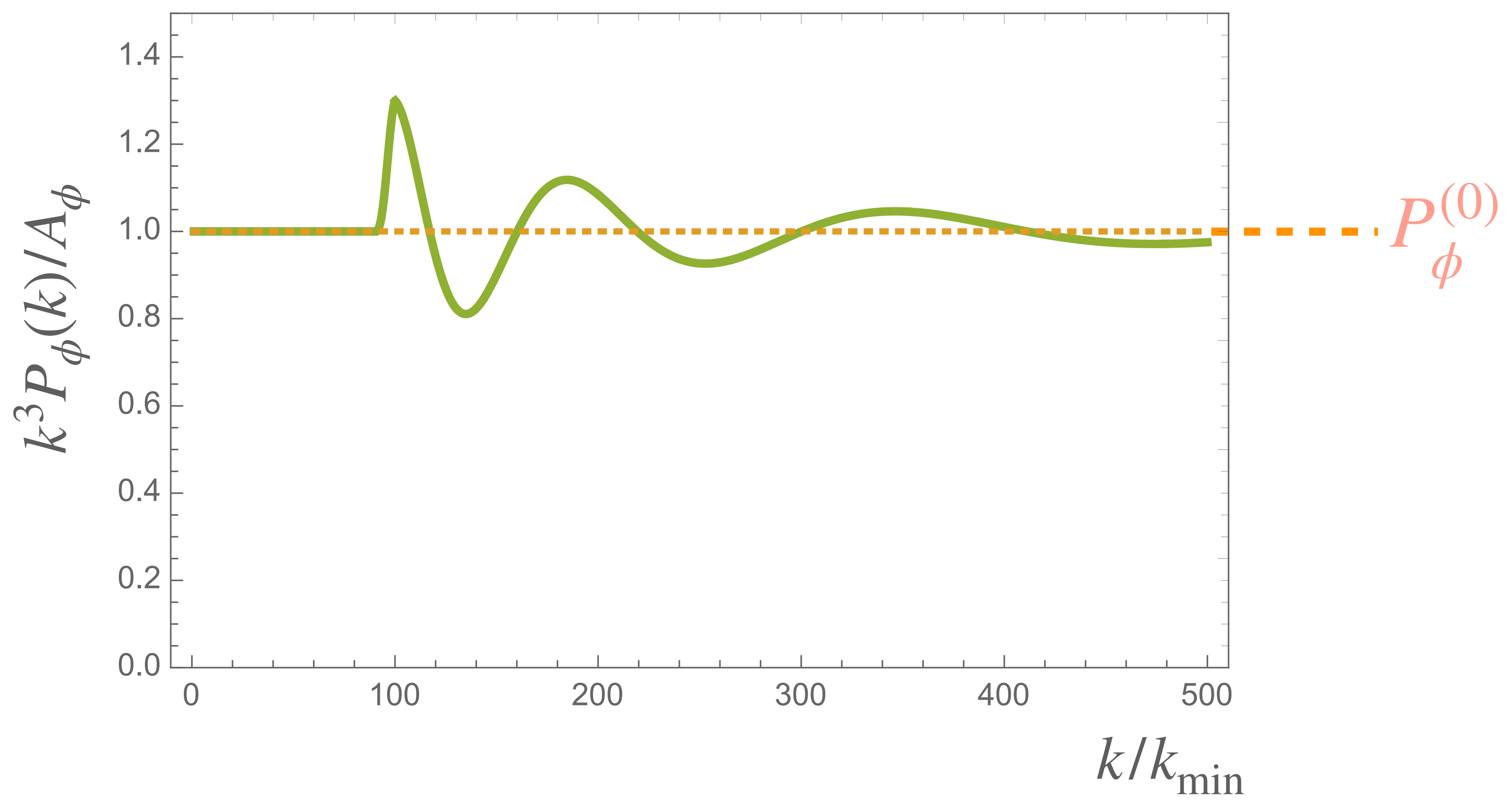
New features

One example is Primordial Clocks: super-heavy fields σ with $M > H$ ($\lesssim 10^{13}\,\mathrm{GeV}$) which are classically excited during inflation.



Gravitationally

Directly



$$\sigma_{\mathrm{VEV}} \propto \cos[M(t - t_0)]$$

$$\frac{\Delta P_\phi(k)}{P_\phi^0} = \theta(k - k_0)\,\alpha \left(\frac{k}{k_0}\right)^{-3/2} \cos\left(\frac{M}{H}\,\mathrm{Log}\frac{k}{k_0}\right)$$

X. Chen, M. Hossein Namjoo, Y. Wang: 1411.2349

- Such primordial clock features have not been found in the CMB.

Planck: 1807.06211, X. Chen, M. Hossein Namjoo, Y. Wang: 1411.2349

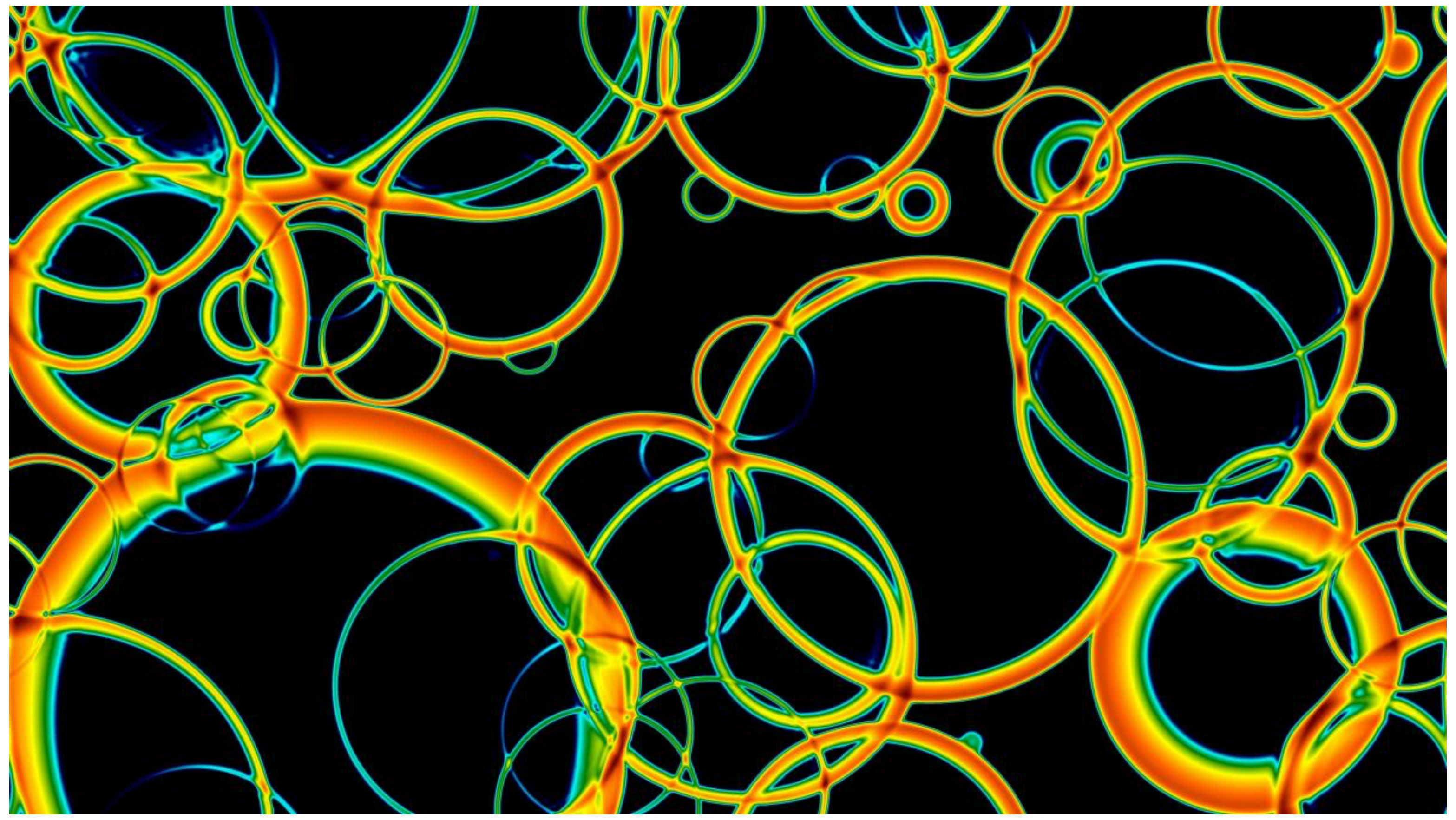
- Constraints are close to the theoretical limit from cosmic variance in $\ell \lesssim O(100)$.

- We ask if there can be other anisotropy maps where such features can be large?

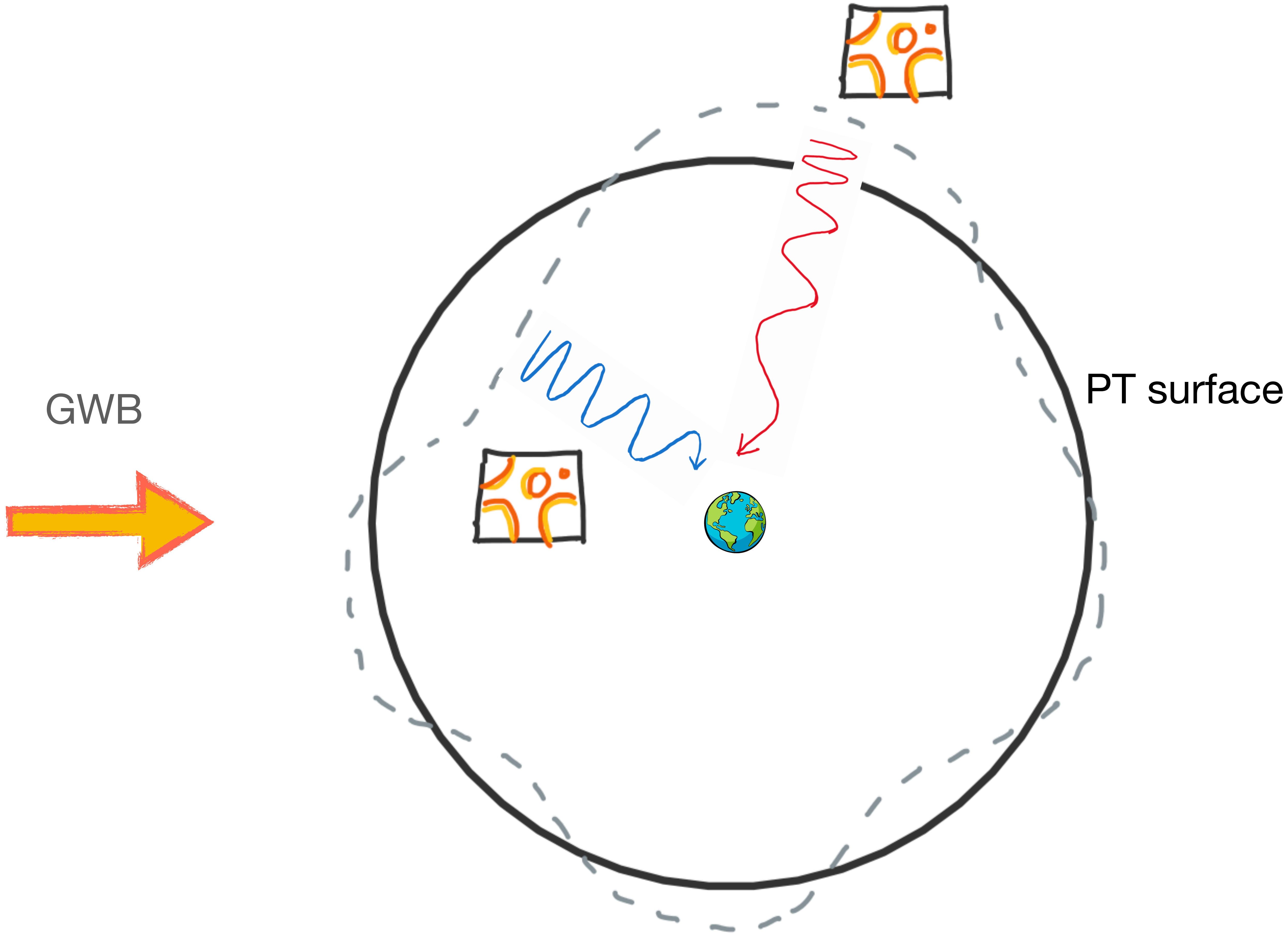
Stochastic gravitational wave background (GWB) from 1st-order phase transitions (PT)

Such GWB will *necessarily* have anisotropies that track underlying density variation of the sector undergoing PT

M. Geller, A. Hook, R. Sundrum, Y. Tsai, 1803.10780

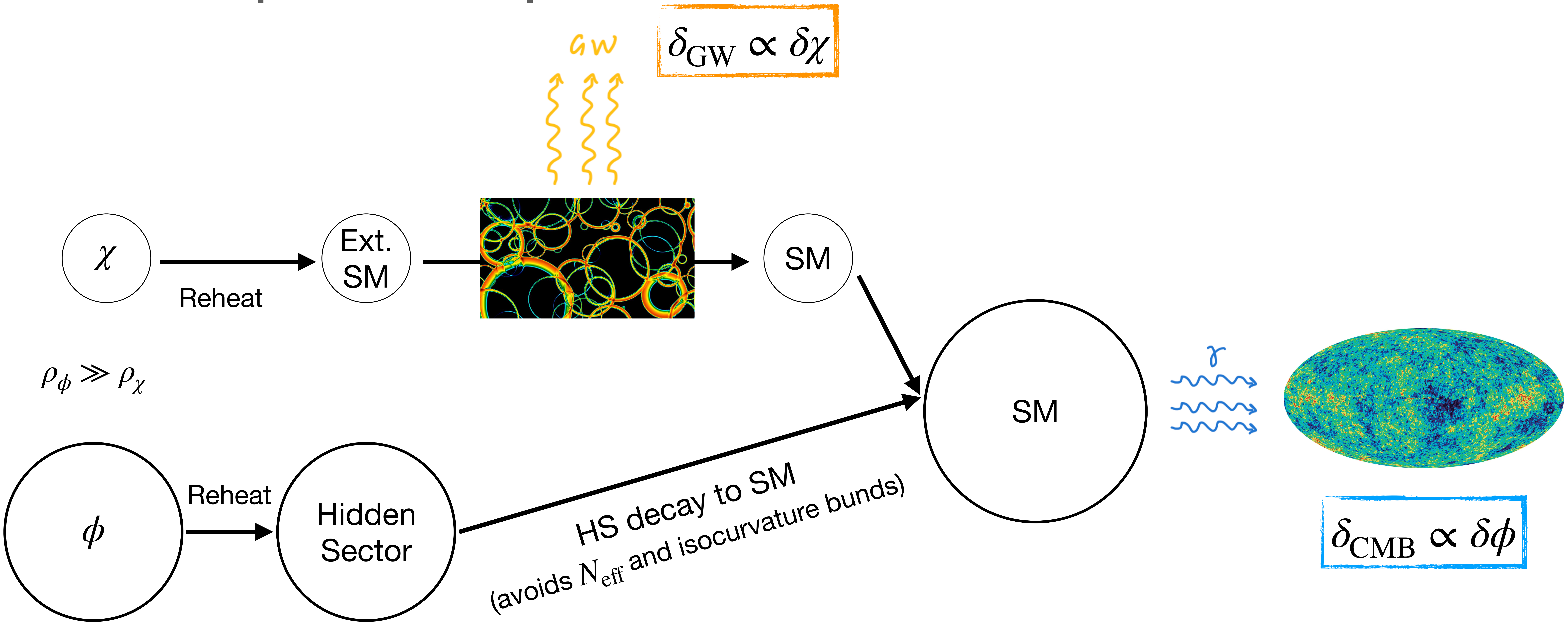


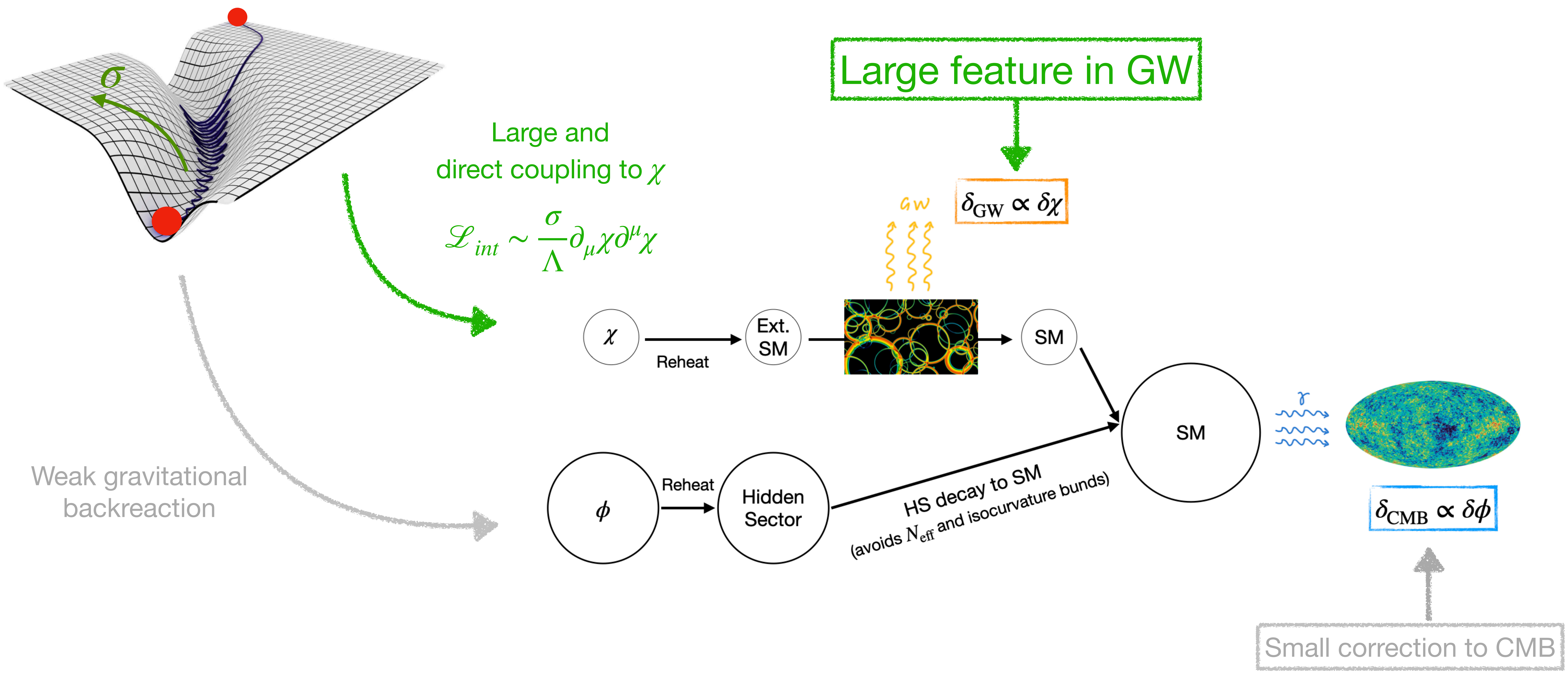
https://www.elisascience.org



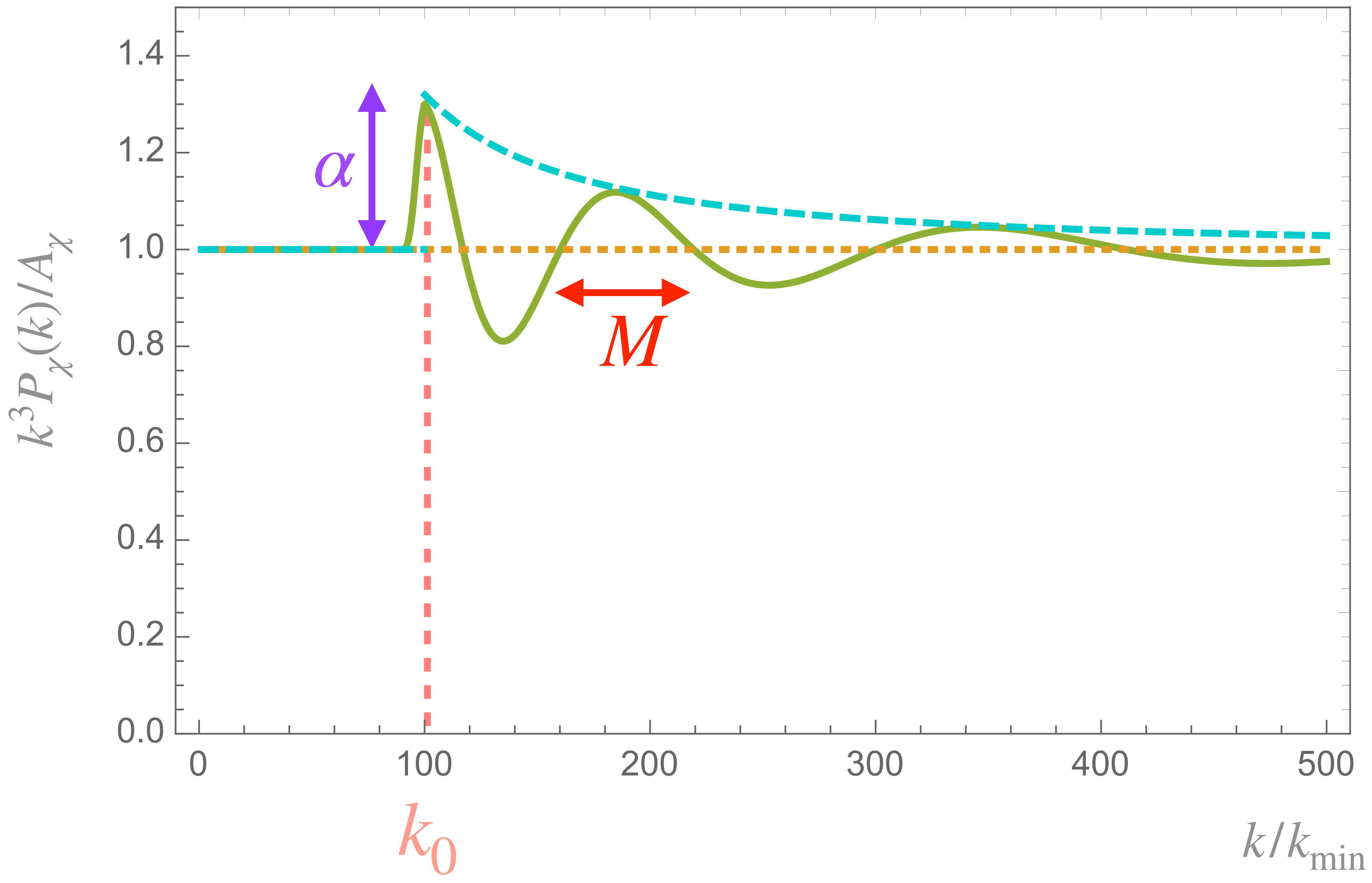
GWB anisotropies could be sourced by a spectator field (χ)

$\Longrightarrow$ Independent map!




Large feature in GW
σ
Large and
direct coupling to χ
$\mathscr{L}_{int} \sim \frac{\sigma}{\Lambda}\partial_\mu\chi\partial^\mu\chi$
$\delta_{\rm GW} \propto \delta\chi$
GW
χ
Reheat
Ext. SM
SM
SM
ϕ
Reheat
Hidden Sector
HS decay to SM
(avoids $N_{\rm eff}$ and isocurvature bunds)
γ
$\delta_{\rm CMB} \propto \delta\phi$
Weak gravitational backreaction
Small correction to CMB

$$\mathcal{L}_{int} \sim \frac{\sigma}{\Lambda}\partial_\mu\chi\partial^\mu\chi \xrightarrow[\text{In-in formalism}]{\text{Oscillations of } \sigma} \Delta P_\chi(k)$$



$$P_\chi(k) = P_\chi^{(0)}(k)\left[1 + \theta(k-k_0)\,\alpha\left(\frac{k}{k_0}\right)^{-3/2}\cos\left(\frac{M}{H}\mathrm{Log}\frac{k}{k_0}\right)\right]$$

Benchmark:

$$\alpha = \sqrt{2\pi}\,\frac{\sigma_0}{\Lambda} = 0.3$$

$$k_0 \approx 100\,k_{\min}$$

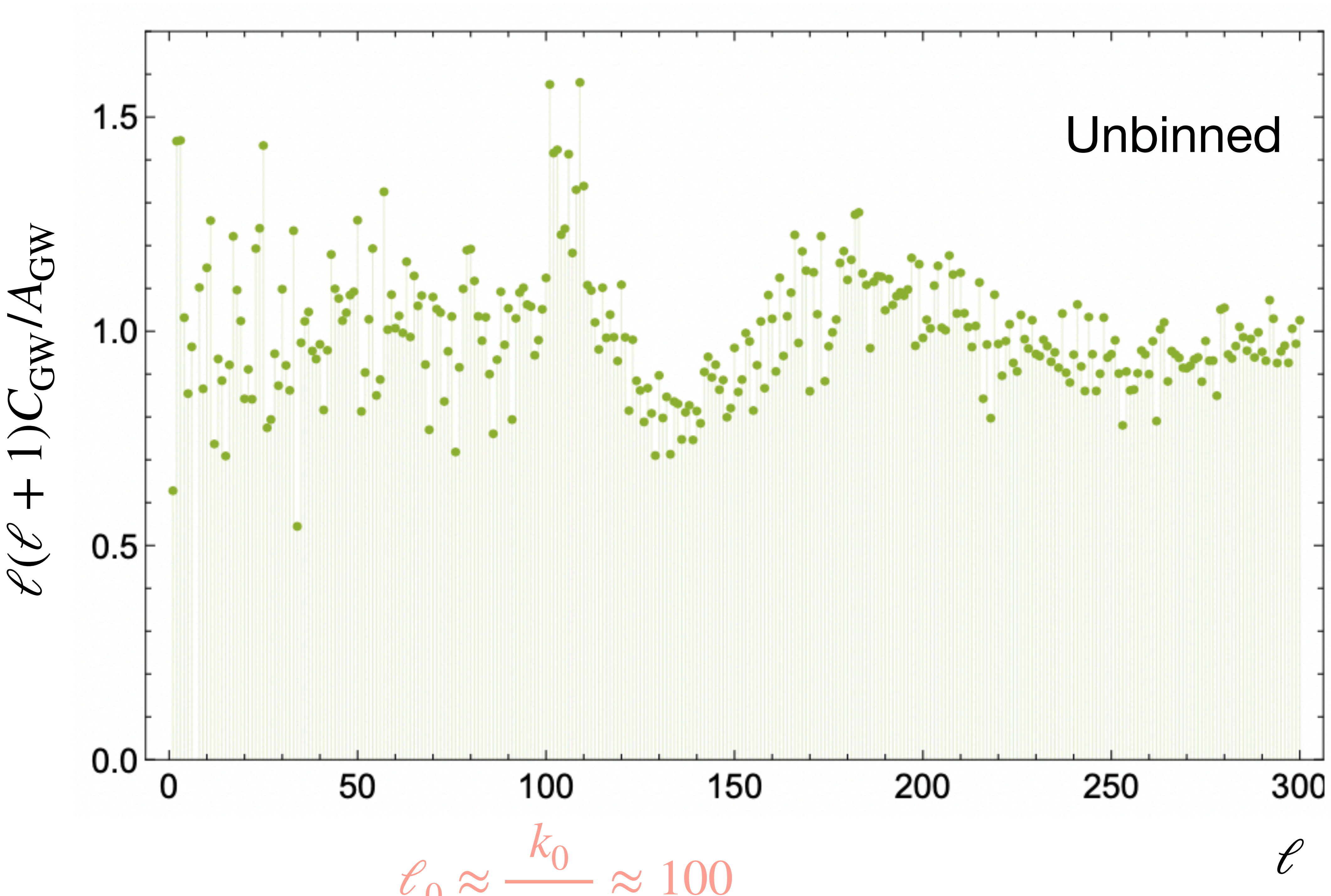
$$M = 10\,H$$

Strong PT: $\beta \sim 5H_{PT}$

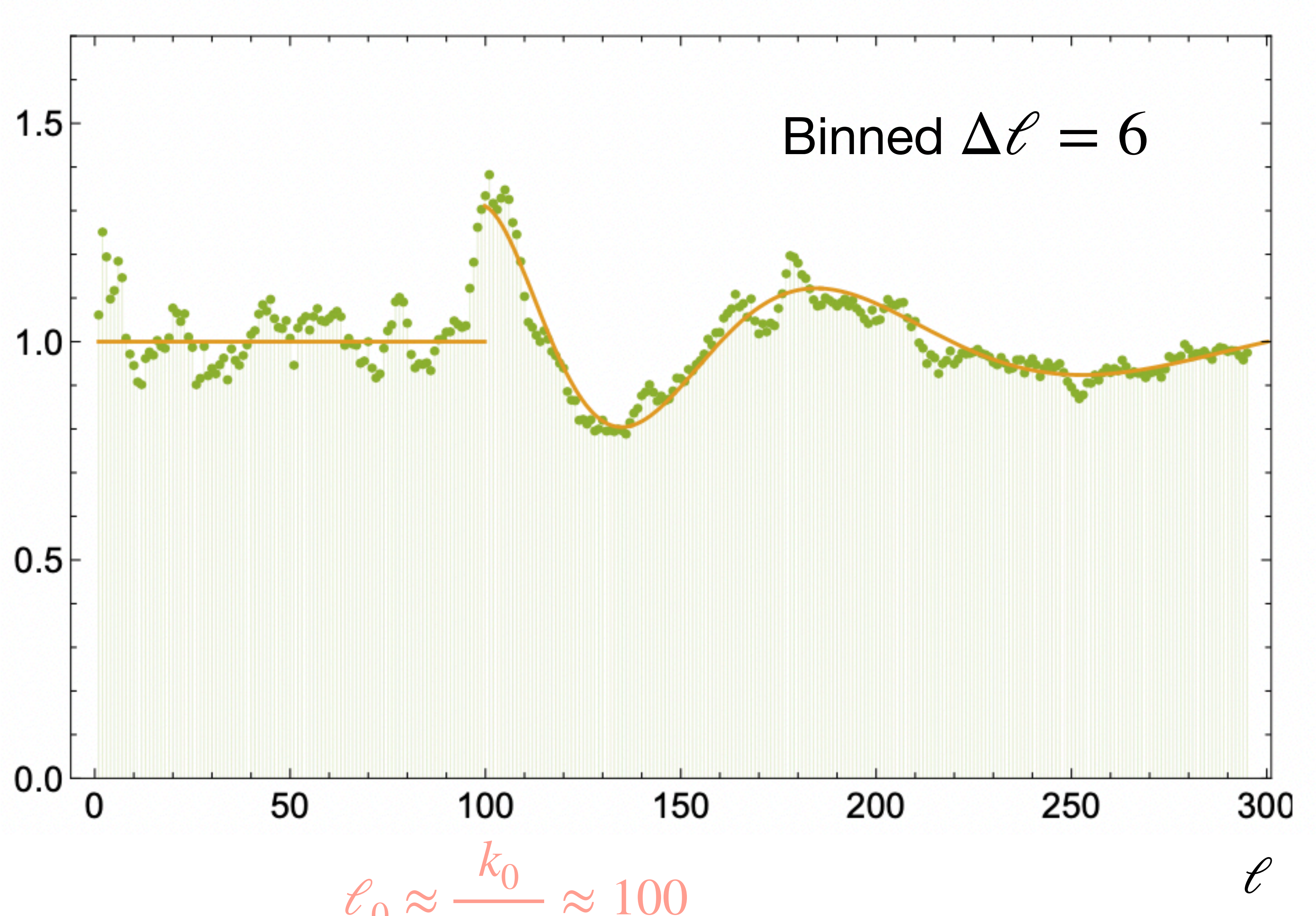
$$\rho_\chi \sim 0.01\rho_\phi$$

$$\delta_\chi \sim \delta_\phi$$

Benchmark + Cosmic variance



$\ell_0 \approx \frac{k_0}{k_{\rm min}} \approx 100$



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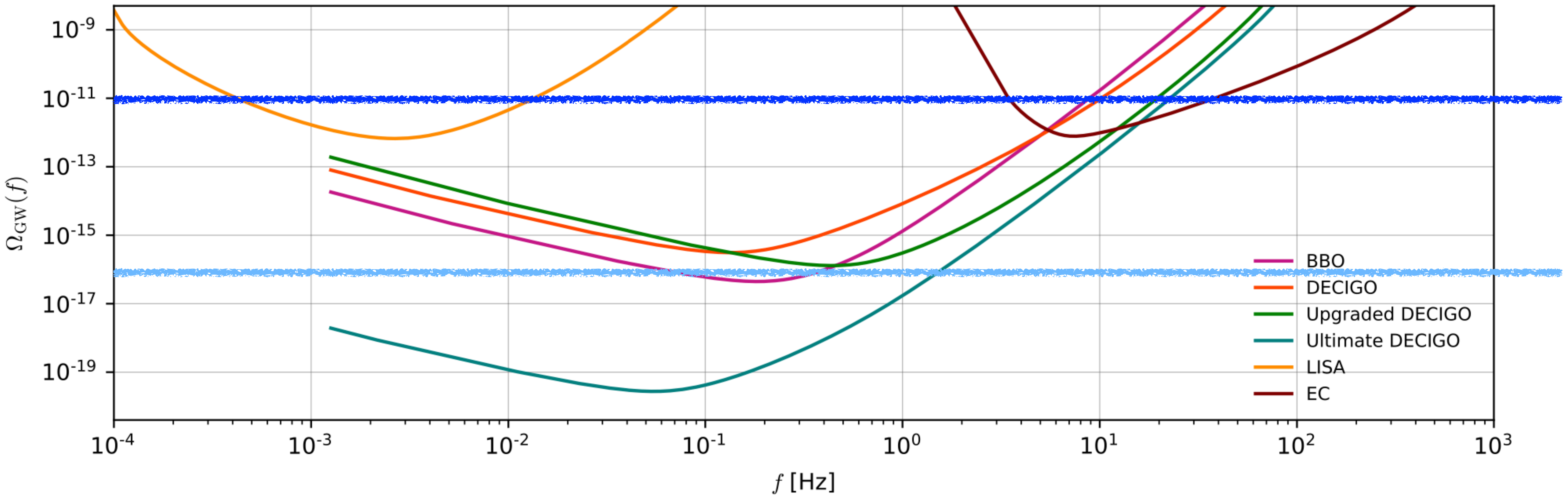
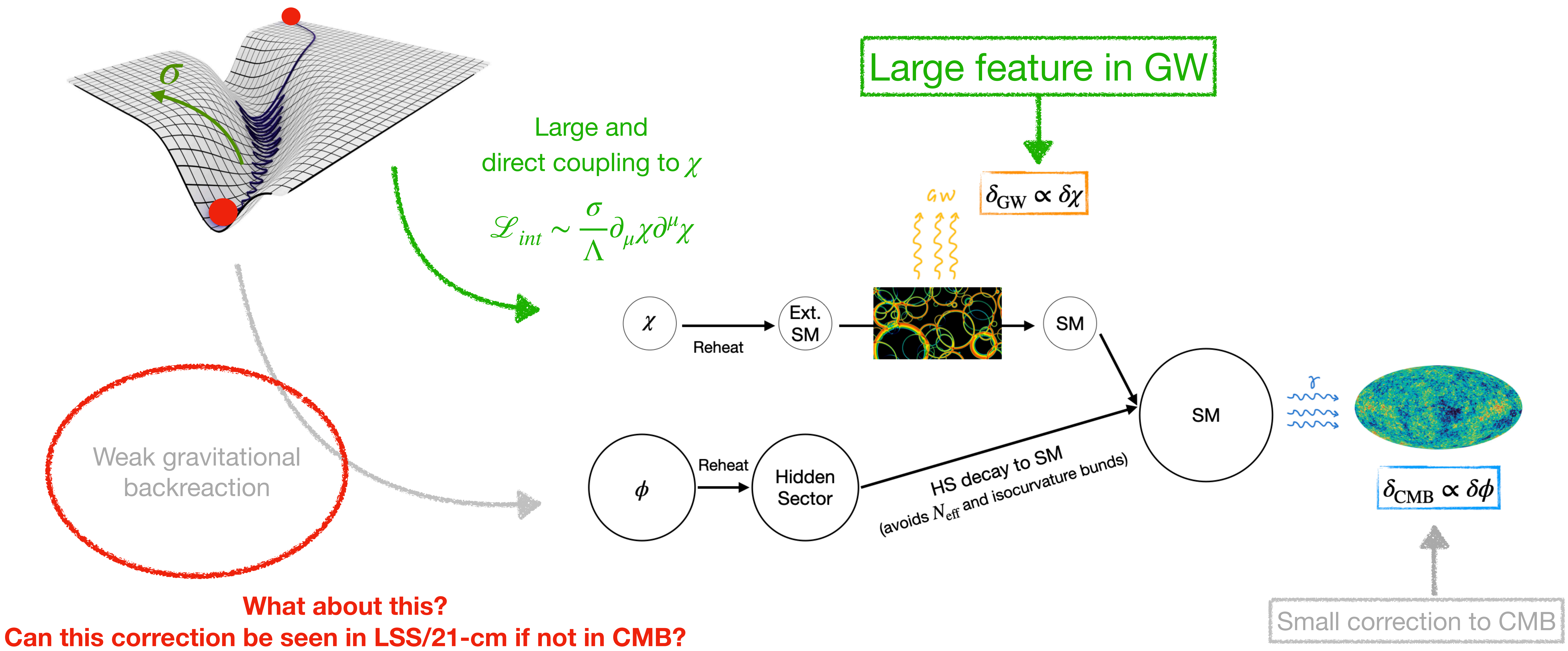
No subhorizon physics can mimic this → must be from inflation!



Isotropic: $\Omega_{GW} \sim 10^{-11}$

Anisotropy: $\delta\Omega_{GW} \sim 8 \times 10^{-17}$

Braglia, Kuronagayi, 2106.03786



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Small correction to CMB
What about this?
Can this correction be seen in LSS/21-cm if not in CMB?

Irreducible corrections in adiabatic perturbations

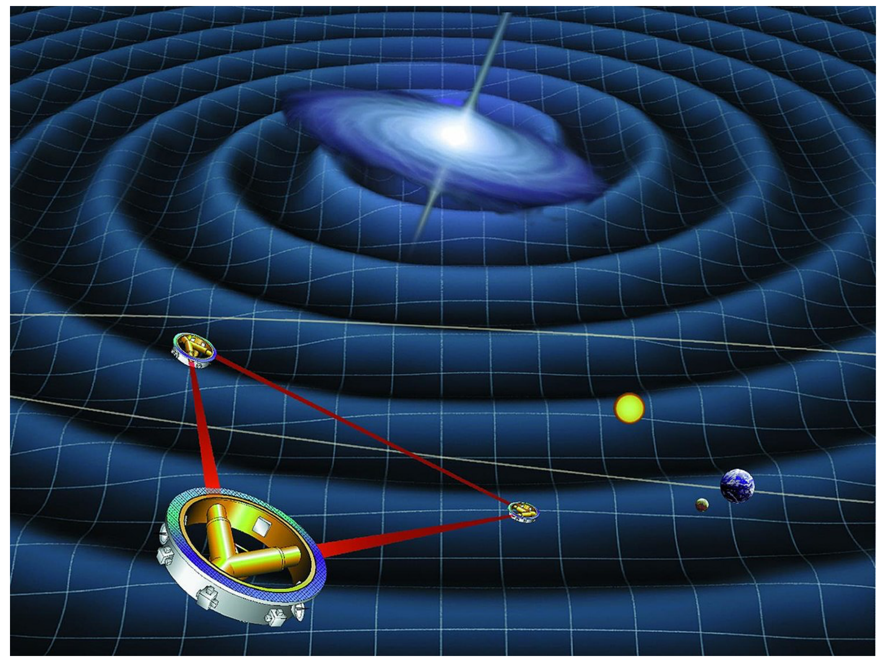
	Corrections	Cosmic variance
Power spectrum $\frac{\Delta P}{P^{(0)}}$	10^{-4}	2D (CMB): $\simeq 10^{-2}$
		3D (LSS, 21-cm): $> 7 \times 10^{-4}$
Non-Gaussianity $f_{\rm NL}$	10^{-3}	2D (CMB): $\simeq 10$
		3D (LSS, 21-cm): $\gtrsim 10^{-2}$

Corrections in ALL adibatic maps can be below the cosmic variance!

Summary:

- GWB could contain new features, even at the level of the power spectrum.
- GW map is less processed by subhorizon physics and makes a more ‘pristine’ map.
- GWB : Interesting features above cosmic variance, but technologically challenging.
  CMB/LSS : experimental precision, but corrections below cosmic variance.
- This analysis can be generalised to other localised features and non-Gaussianities.
- Can there is other maps?

Thank You!



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