

Cornering Extended Starobinsky Inflation with CMB and SKA

Benedikt Schosser together with Tanmoy Modak, Tilman Plehn, Lennart Röver, Björn Malte Schäfer

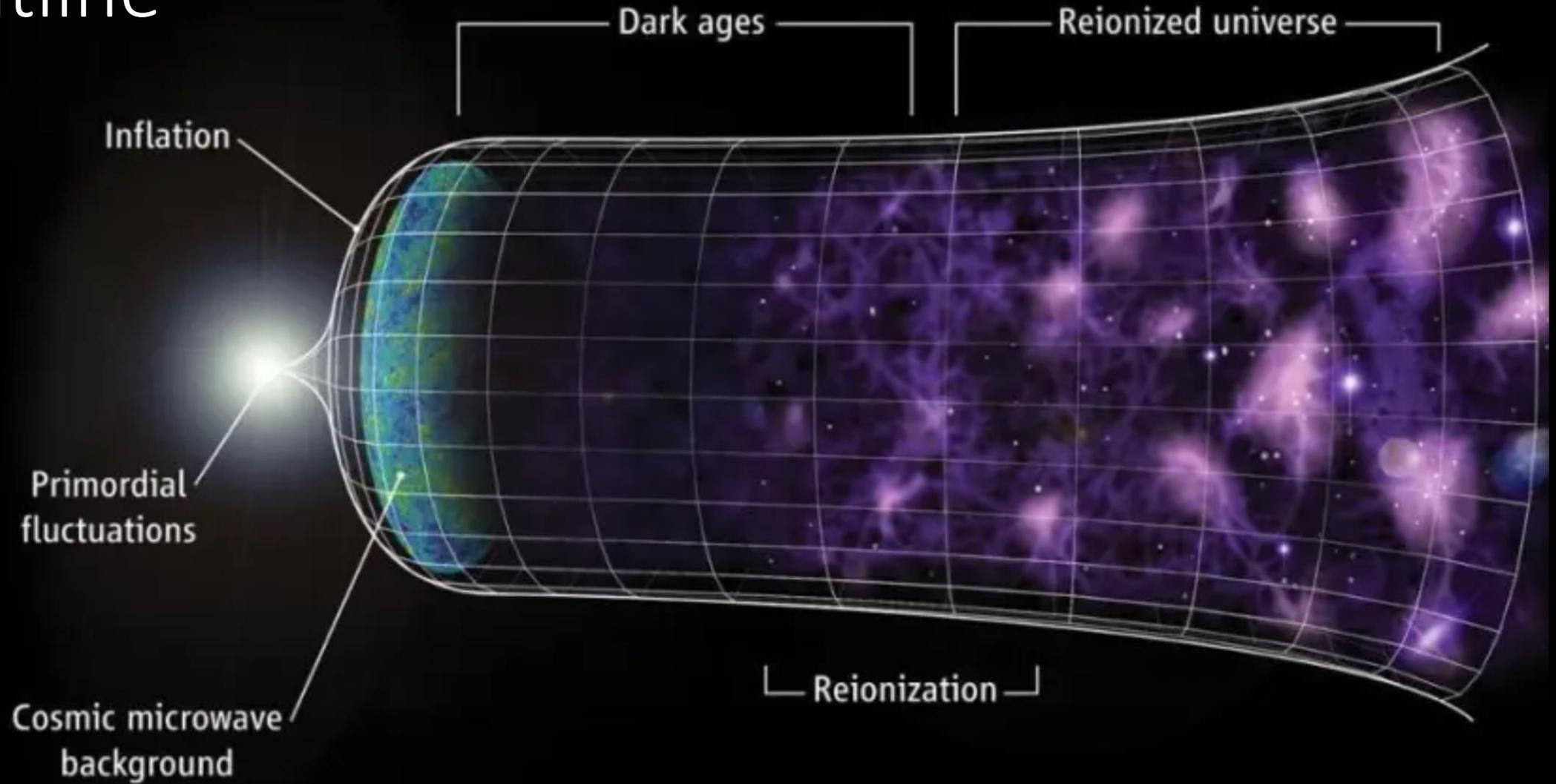
Heidelberg University

arXiv:2210.05695

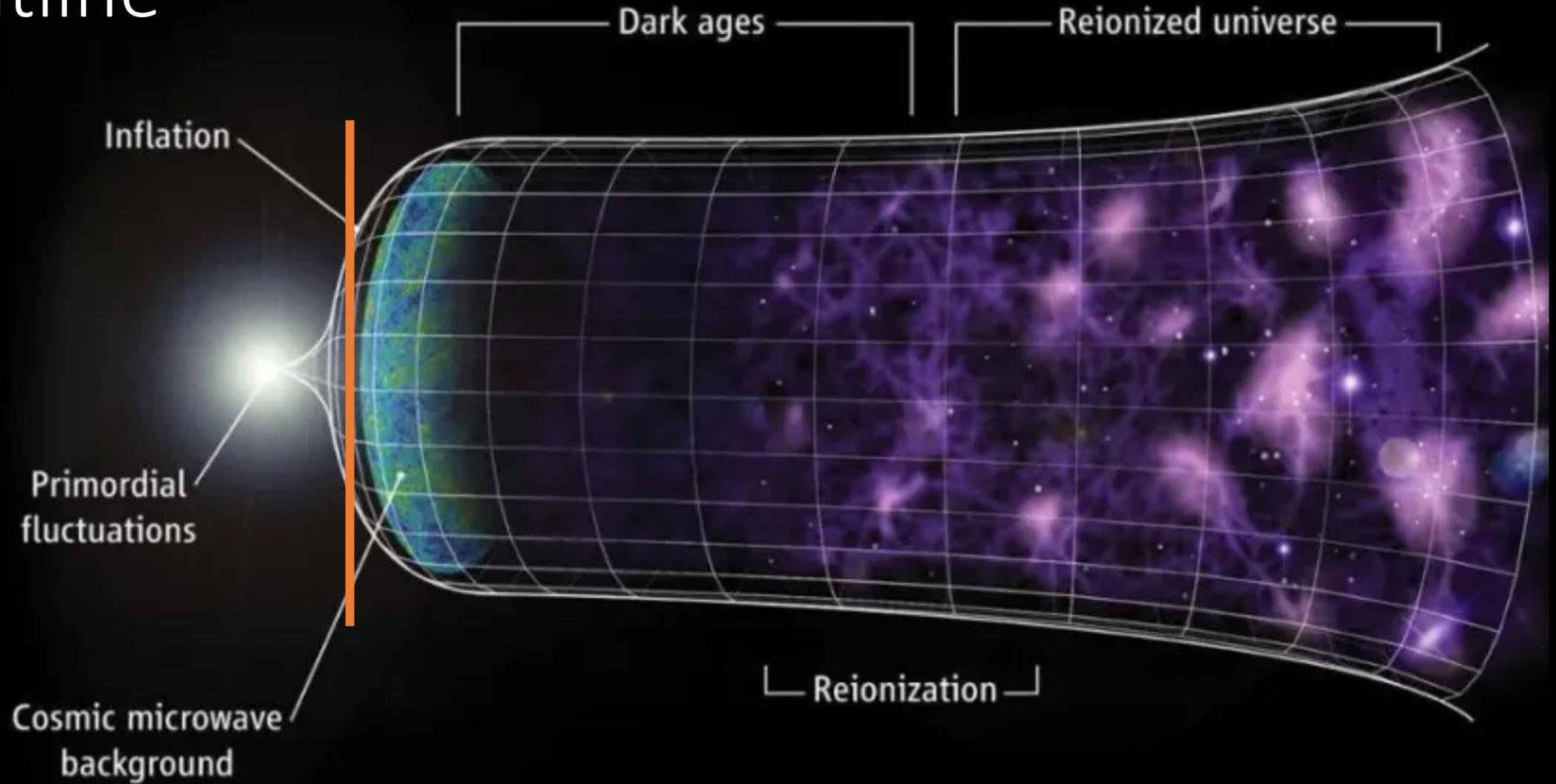
Phenomenology Symposium May 8, 2023

University of Pittsburgh

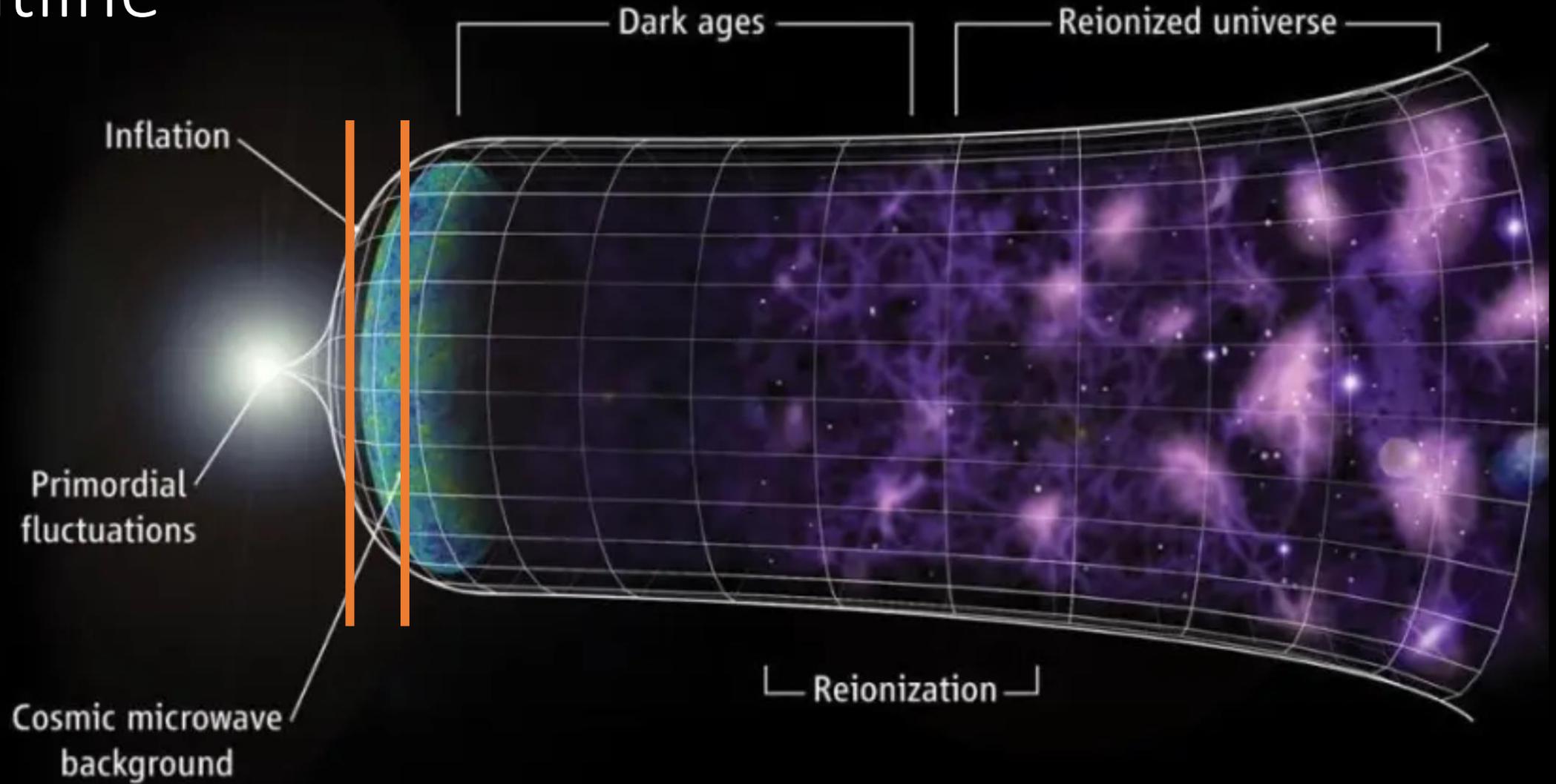
Outline



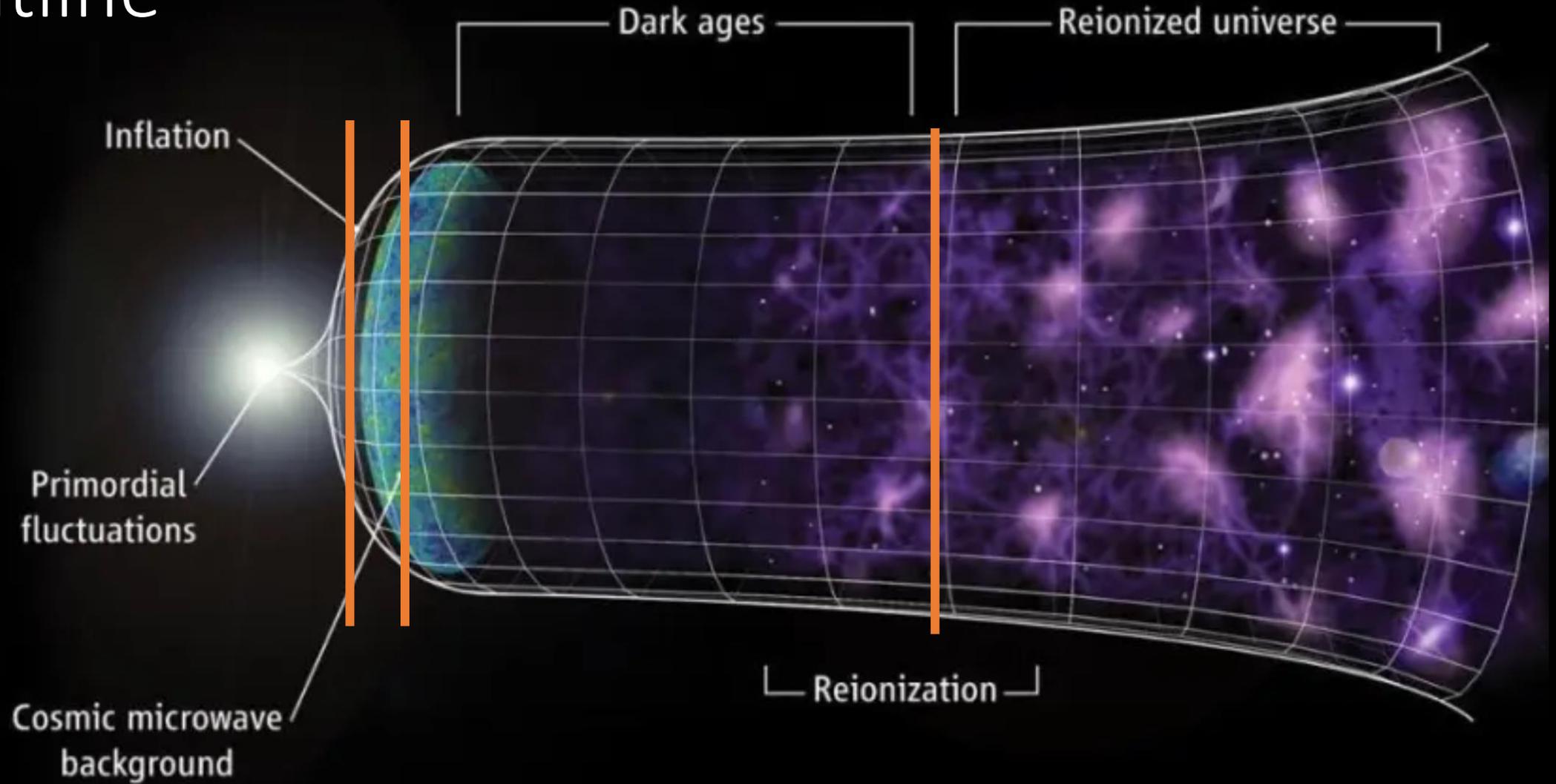
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Motivation

Goal: Explain inflation with gravity

$$\mathcal{L}_{EH} = \frac{M_P^2}{2} \sqrt{-g} R$$

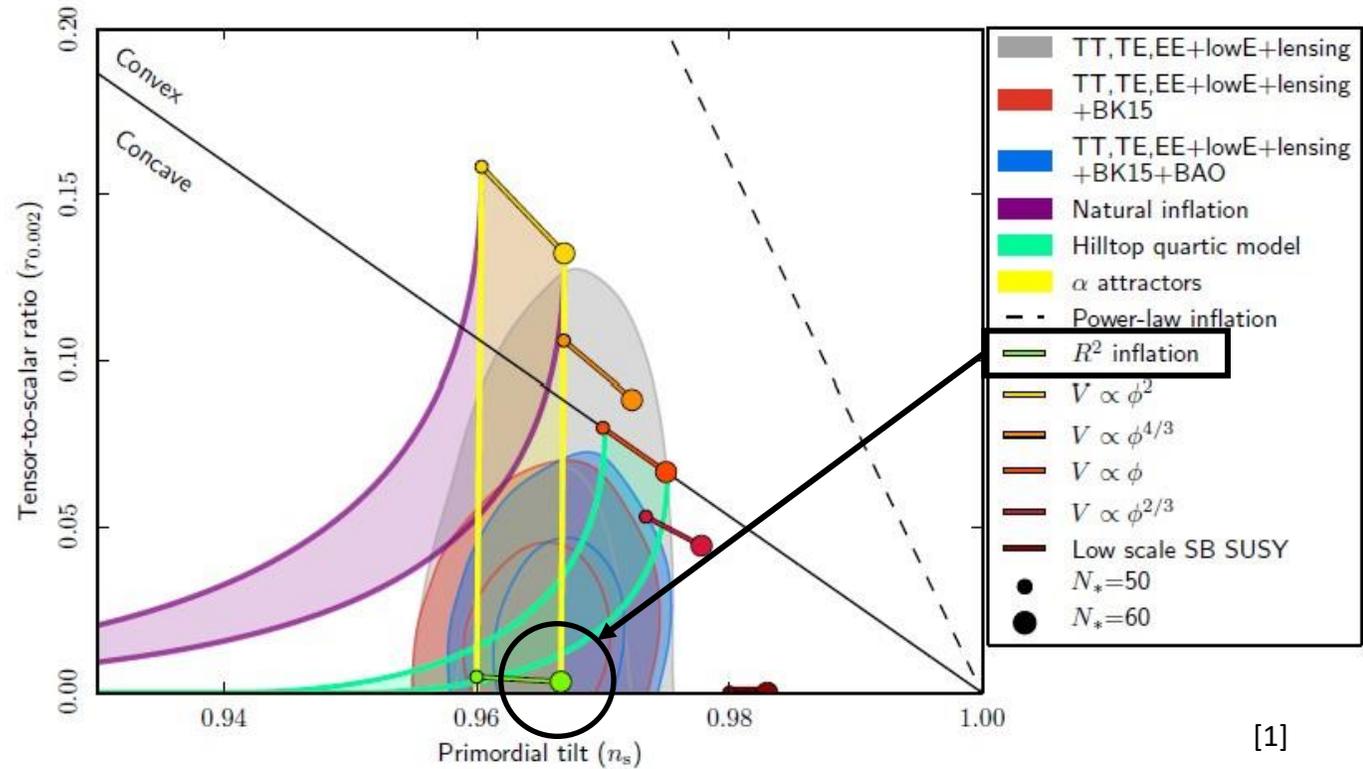
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↓ Starobinsky-inflation is the best-fit model

$$\mathcal{L}_{St} = \frac{M_P^2}{2} \sqrt{-g} \left(R + \frac{1}{6M^2} R^2 \right)$$



[1]

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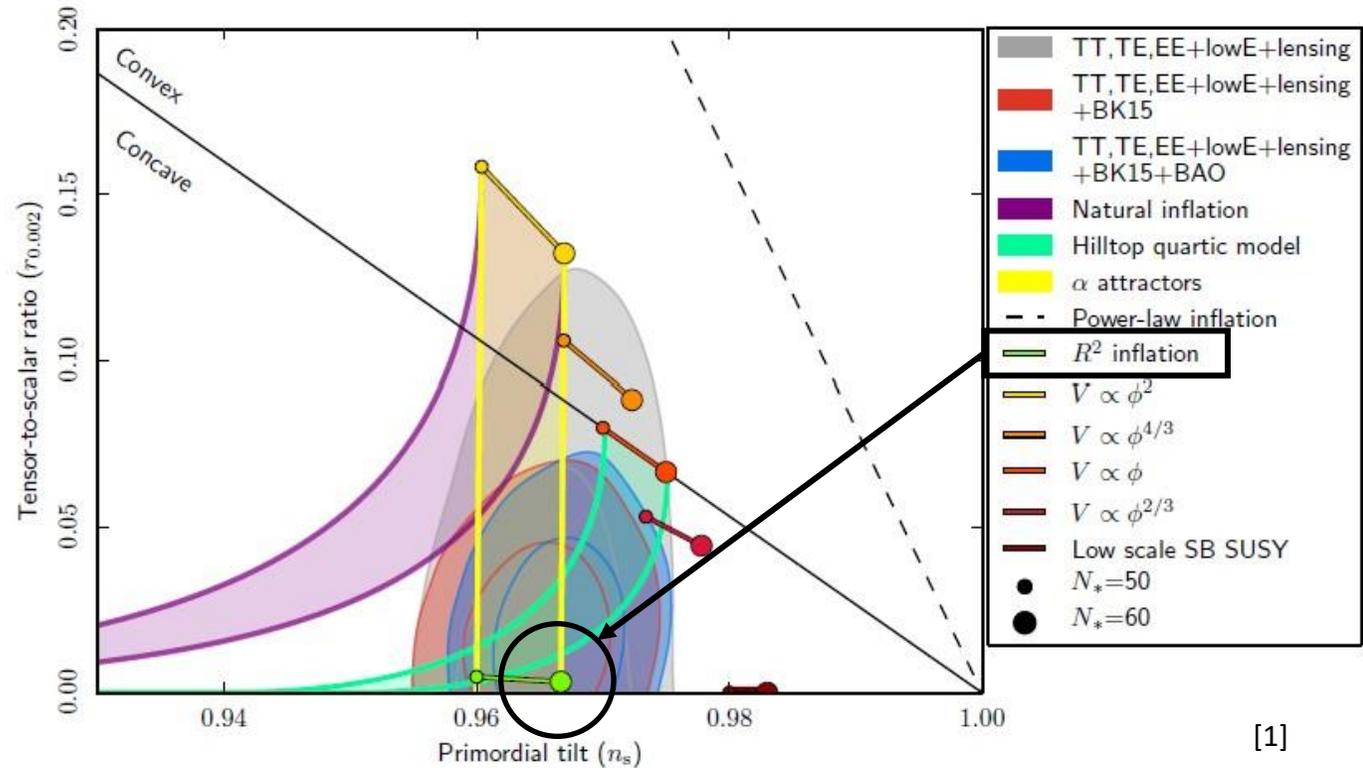
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$$\mathcal{L}_{St} = \frac{M_P^2}{2} \sqrt{-g} \left(R + \frac{1}{6M^2} R^2 \right)$$

↓ Include higher order terms: $f(R)$ -gravity

$$\mathcal{L}_{(3)} = \frac{M_P^2}{2} \sqrt{-g} \left(R + \frac{1}{6M^2} R^2 + \frac{c}{36M^4} R^3 \right)$$



[1]

Inflaton Potential

$$S_J = \int d^4x \sqrt{-g_J} \frac{M_P^2}{2} \left(R + \frac{1}{6M^2} R^2 + \frac{c}{36M^4} R^3 \right)$$

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Scalar field φ

Einstein-Jordan
duality



$$S_E = \int d^4x \sqrt{-g_E} \left[\frac{M_P^2}{2} R_E - \frac{1}{2} g_E^{\mu\nu} \nabla_\mu \varphi \nabla_\nu \varphi - V_E(\varphi) \right]$$

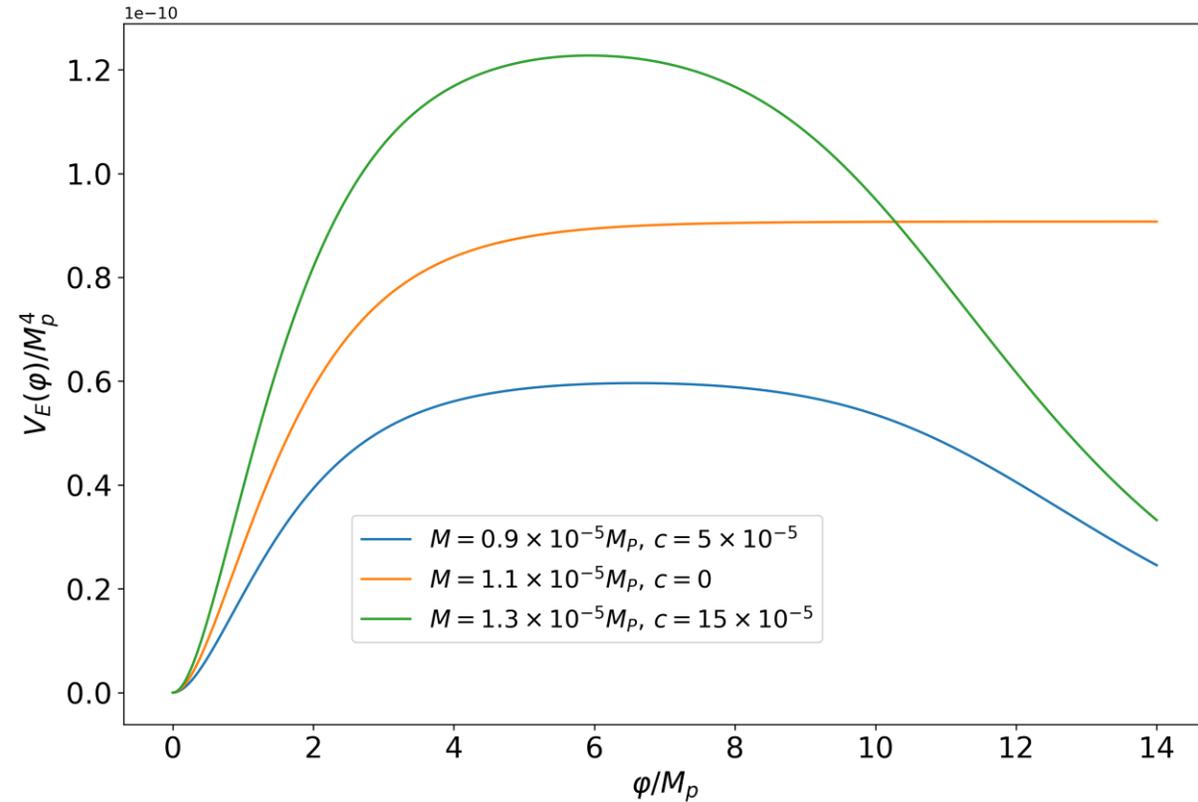
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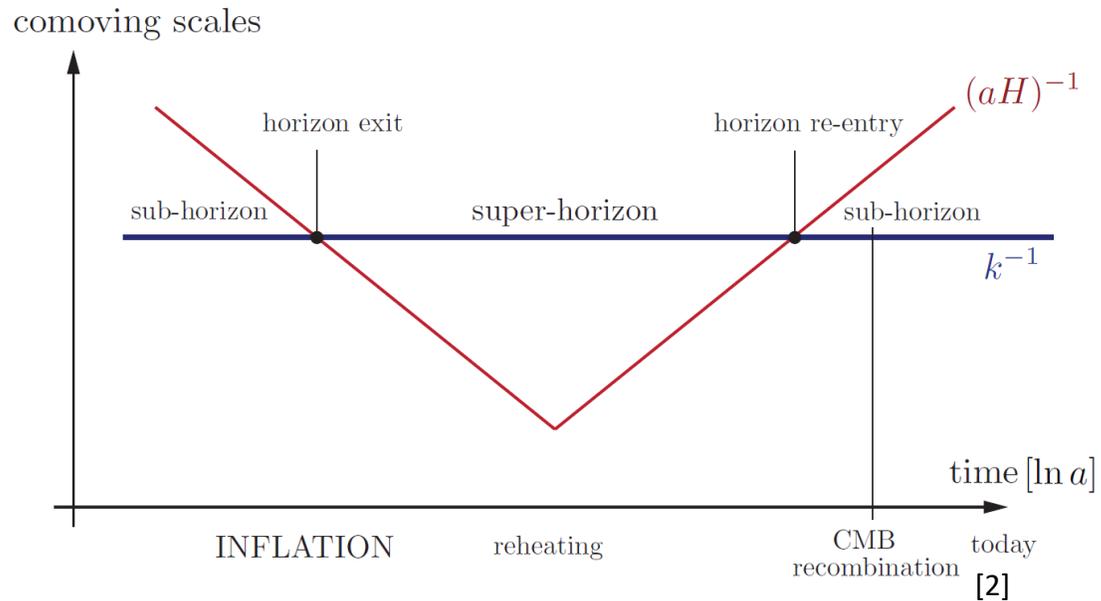
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Contact with Observations



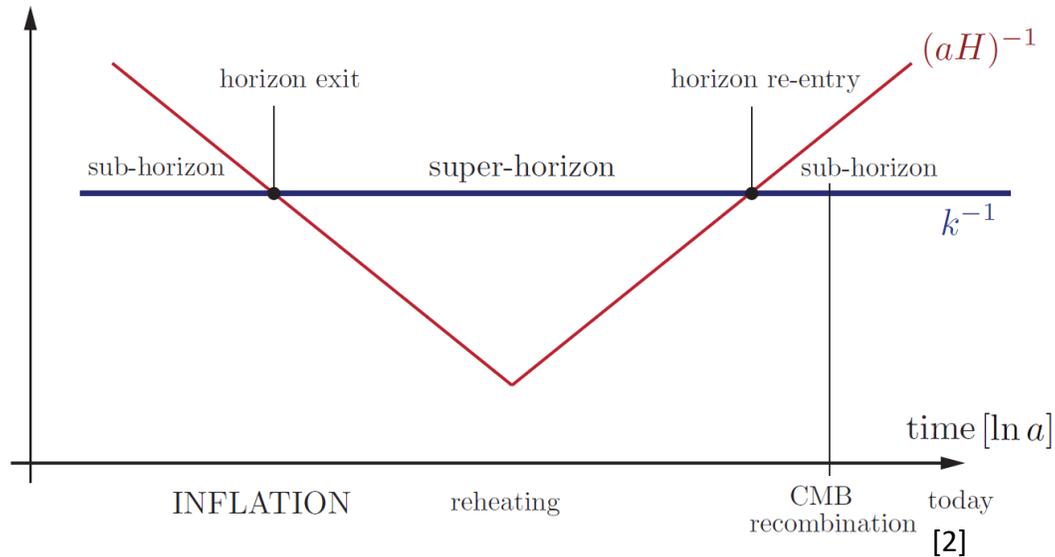
Quantum fluctuations in φ

² Baumann: TASI Lectures on Inflation, arXiv:0907.5424v2

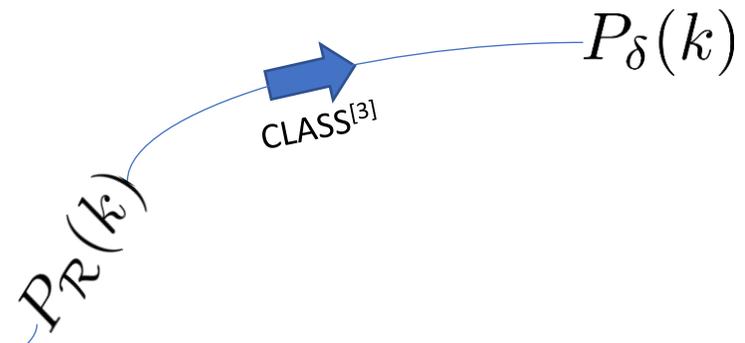
³ The Cosmic Linear Anisotropy Solving System (CLASS), arXiv:1104.2932

Contact with Observations

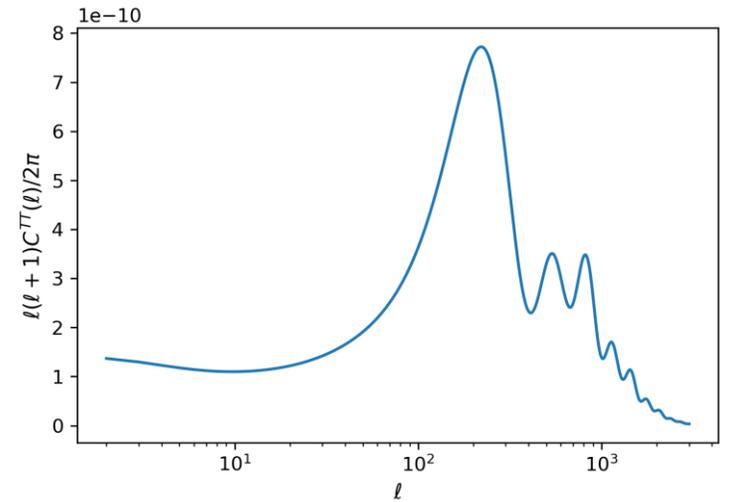
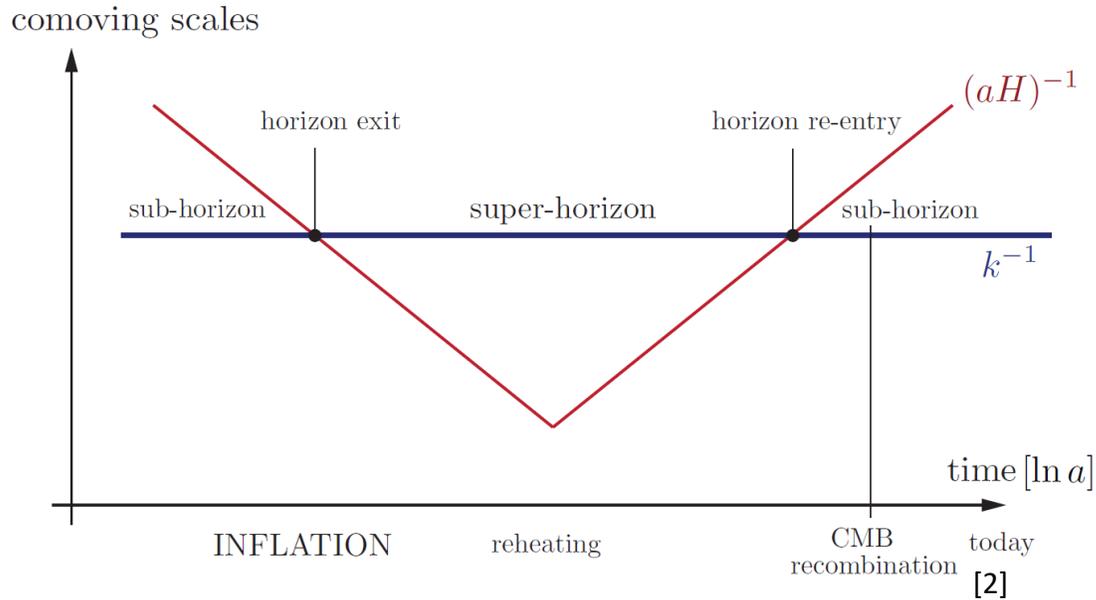
comoving scales



Quantum fluctuations in φ



Contact with Observations

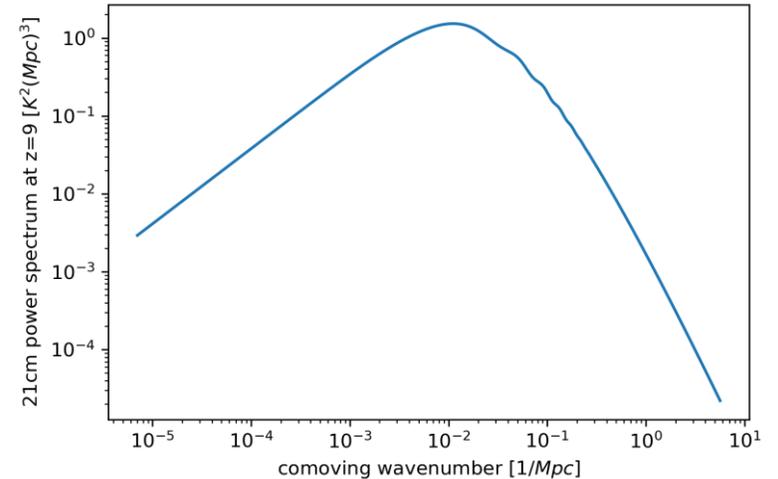


$P_\delta(k)$

CLASS^[3]

$P_R(k)$

Quantum fluctuations in φ



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21cm intensity mapping

Want: Matter distribution at high redshift: $z = 8 - 10$

21cm intensity mapping

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- Measure 21cm hyperfine transition
- Find power spectrum
- 21cm power spectrum traces DM power spectrum

$$P_{21}(k) \longrightarrow P_{\delta}(k)$$

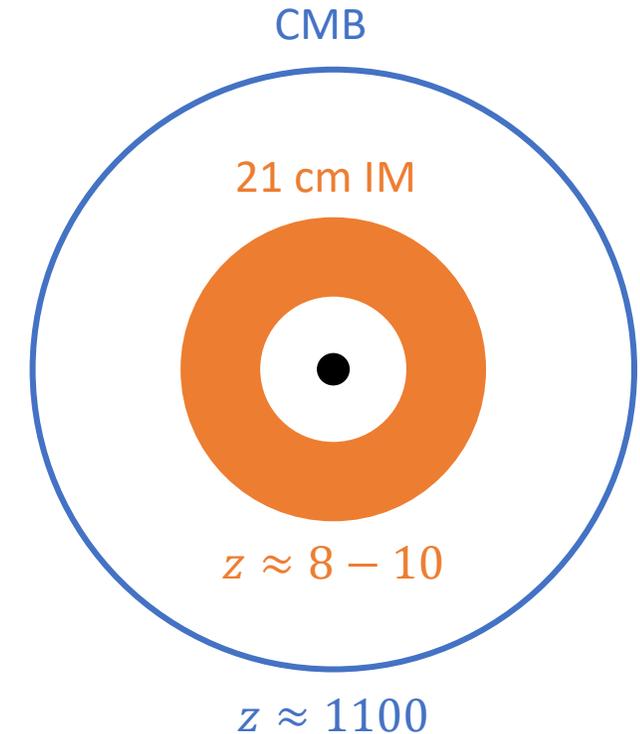
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Experiments

Past | Future

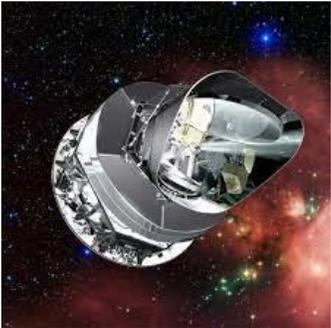
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Experiments

Past

Future

Planck



[5]

- Satellite CMB experiment

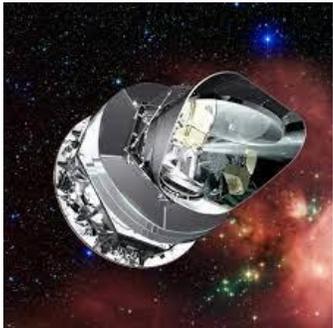
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Experiments

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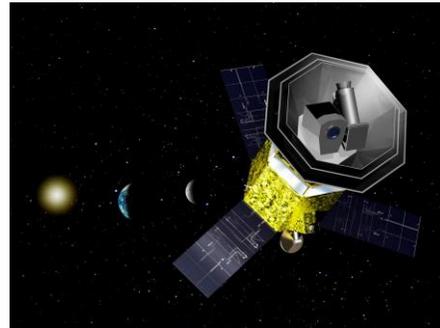
Future

Planck



[5]

LITEbird



[6]

CMB-S4



[7]

Square Kilometre Array (SKA)



[8]

- Satellite CMB experiment

- Satellite CMB experiment
- Highest sensitivity for $2 < \ell < 1350$

- Ground-based CMB experiment
- Highest sensitivity for $30 < \ell < 3000$

- Ground-based
- 2 radio telescope arrays
- Observes large scale structure

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Results

Method:

- Sample the parameter-set $\{\omega_b, \omega_{cdm}, h, \tau_{reio}, M, c, N_\star\}$
- Calculate observables with CLASS
- Add gaussian prior with $\mu = 55, \sigma = 5$ for N_\star
- Use MCMC-tool MontePython ^[9] to get posterior

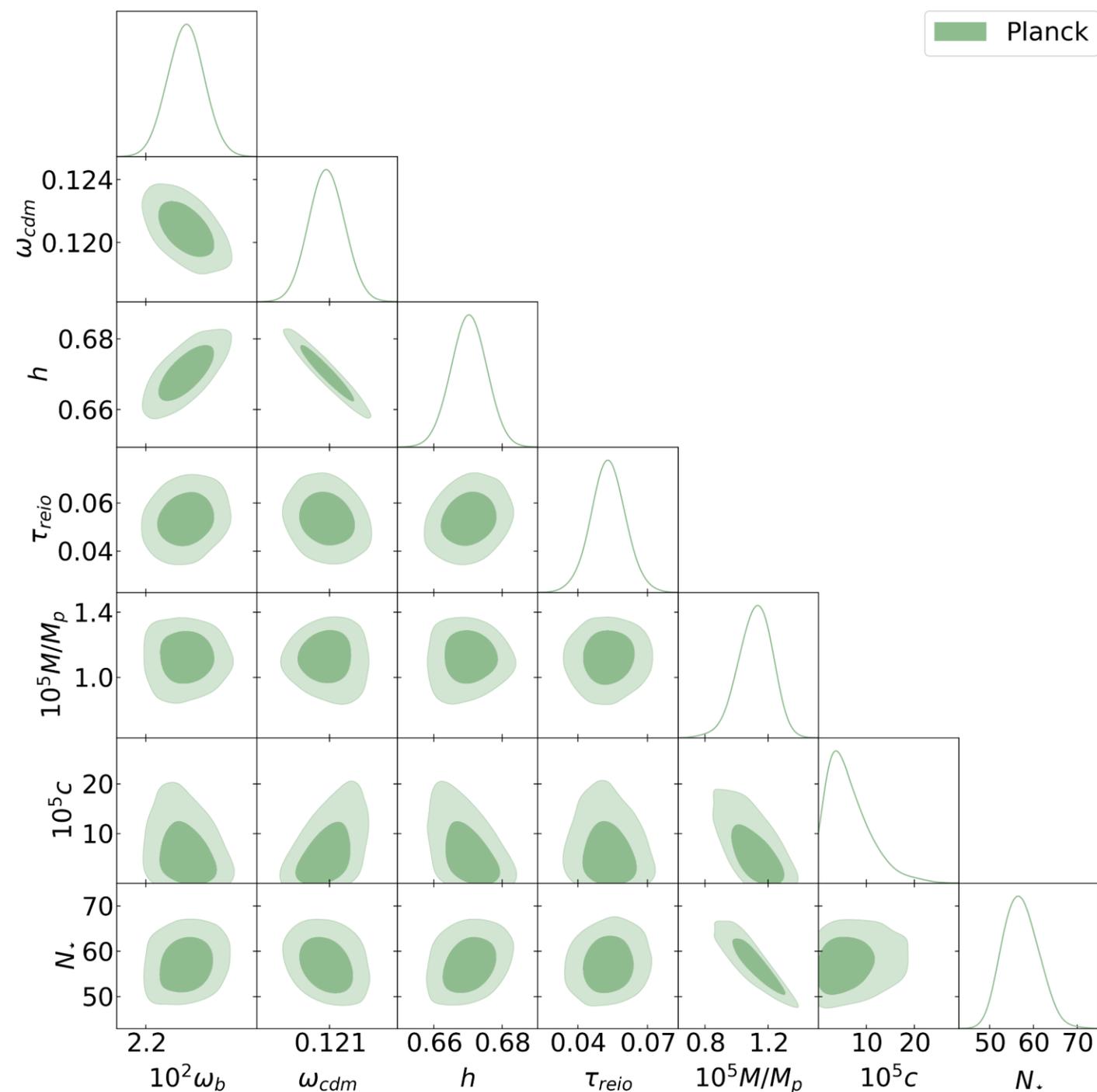
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Parameter	95% limits
$10^5 M/M_p$	$1.12^{+0.21}_{-0.22}$
$10^5 c$	$6.1^{+9.9}_{-6.1}$
N_\star	57^{+8}_{-8}



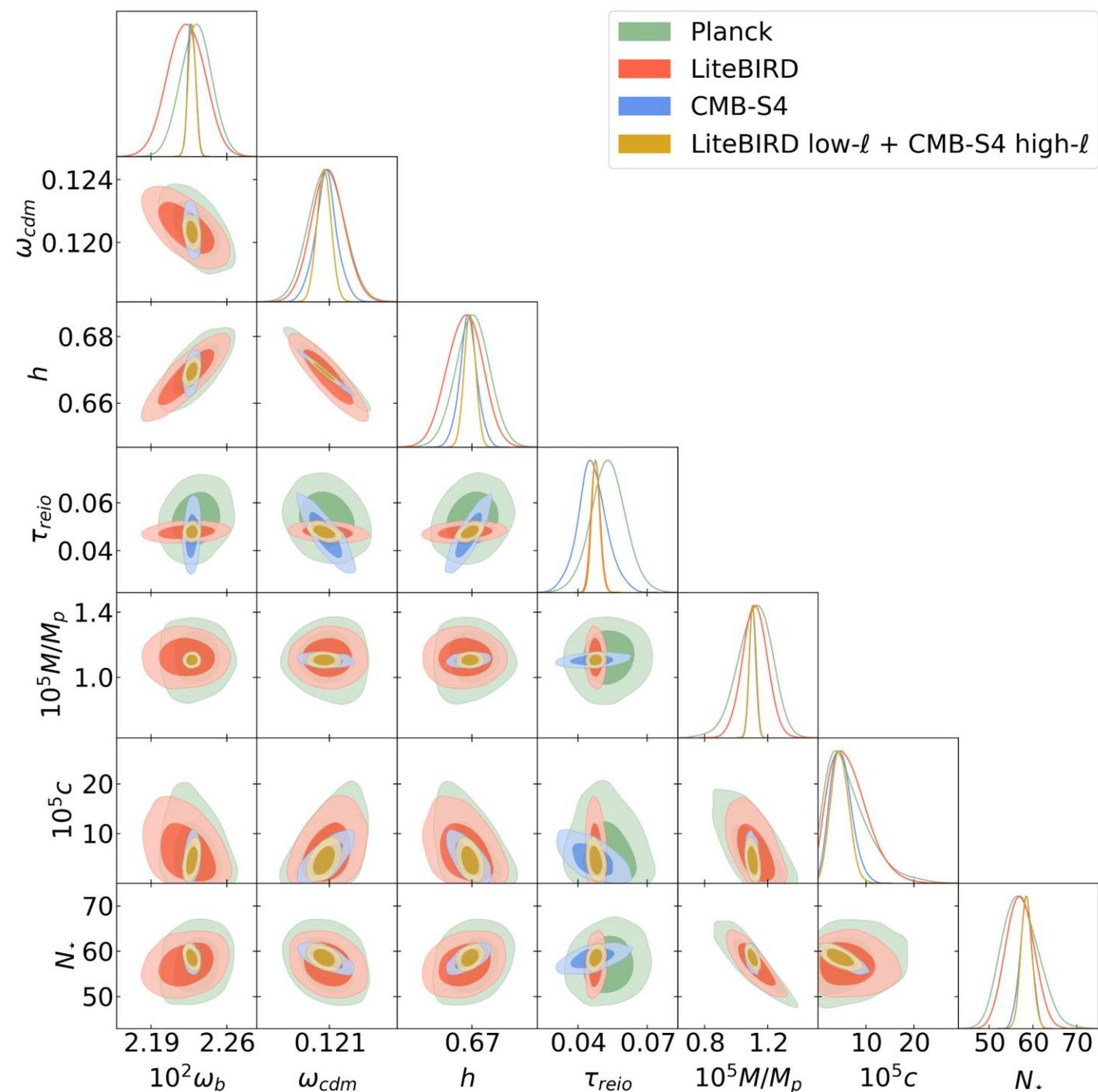
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Forecasts - CMB

Use Planck best-fit value as fiducial value for forecasts



Next generation CMB experiments can exclude $c = 0$, if $c > 4 \cdot 10^{-5}$

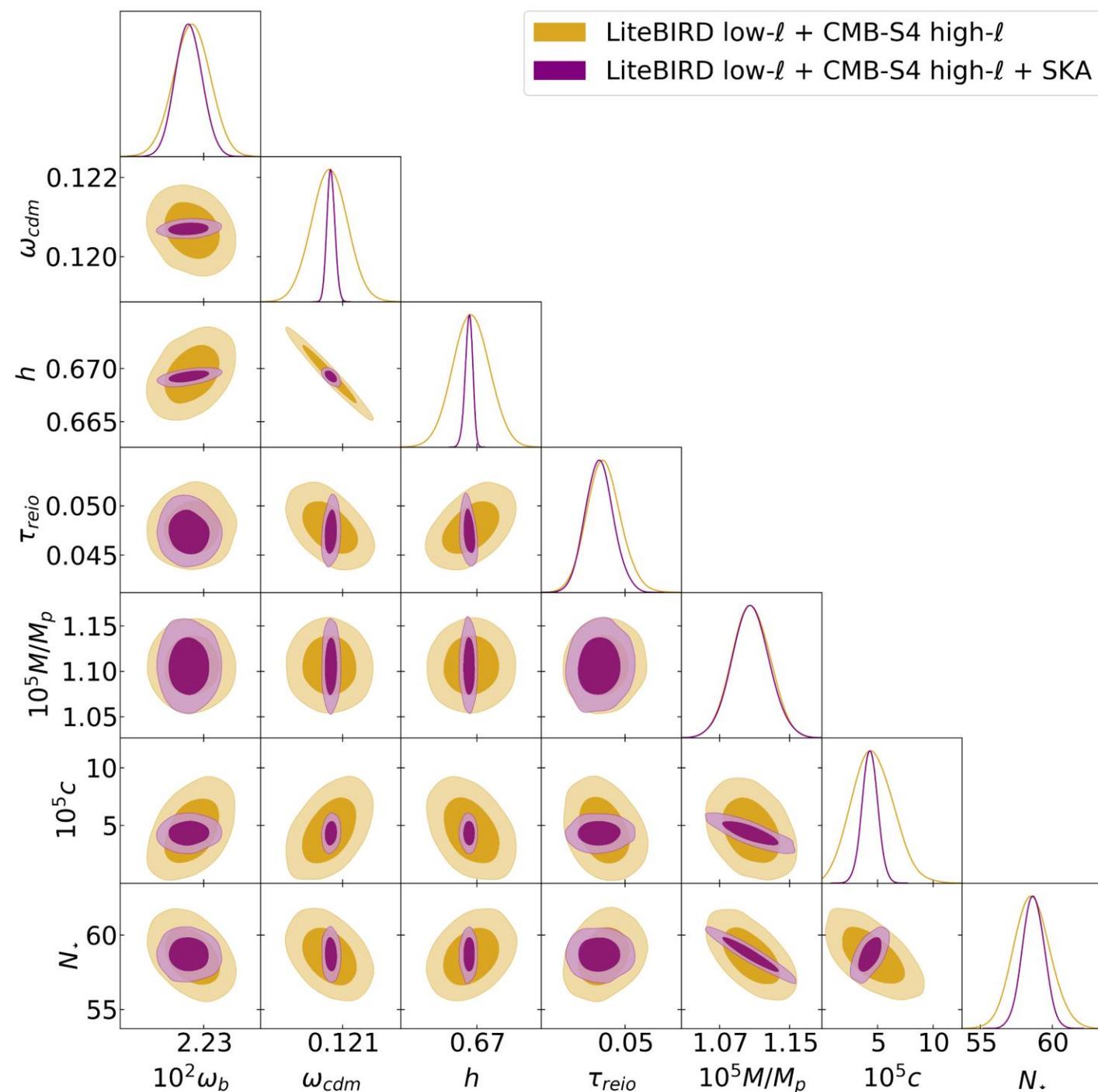


Forecasts - SKA

Use Planck best-fit value as fiducial value for forecasts



Next generation CMB and 21 cm experiments can exclude $c = 0$, if $c > 2 \cdot 10^{-5}$



Summary

- Extending Starobinsky-inflation to third-order $f(R)$ -gravity is natural
- Best-fit to the Planck measurements is for $c = 4.315 \cdot 10^{-5}$
- Combination of next generation CMB and 21cm experiments could exclude $c = 0$

$$\mathcal{L}_{(3)} = \frac{M_P^2}{2} \sqrt{-g} \left(R + \frac{1}{6M^2} R^2 + \frac{c}{36M^4} R^3 \right)$$

