CONSTRAINTS ON THE PRIMORDIAL UNIVERSE THROUGH THE CMB POLARISATION

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The CMB presents polarised anisotropies

Generated by primordial gravitational waves
Scaled by the tensor-to-scalar ratio $r$

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Constraints on the parameter → Uncertainties on the cosmological observable

Parameter → Cosmological Observable

Model

Observation
Model

Parameter

Constraints on the parameter

Cosmological Observable

$C_{XY}^{\ell}$

Uncertainties on the cosmological observable

$\Delta C_{XY}^{\ell}$

Observation

Noise, beam, partial sky coverage

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Uncertainties on $C_{\ell}^{XY}$: the mode-counting variance

$$\Delta C_{\ell}^{XX} = \frac{2\delta_{\ell\ell'}}{(2\ell + 1)f_{sky}}(C_{\ell}^{XX} + \text{noise})^2$$

Pro:
- Analytic expression: easy to compute

Con:
- Underestimation: ideal variance
Uncertainties on $C_{XY}^{\ell}$: the pure estimation

Method:
- Estimation of clean B-modes power spectrum (exact E/B separation)
- Optimizing the applied mask

Pro:
- **Realistic** estimation

Con:
- Monte Carlo simulations

From Ferté et al., *PRD* (2013)
Model

Parameter

Constraints on the parameter

Fisher matrix

Cosmological Observable

$C_{\ell}^{XY}$

- Mode Counting
- Pure method

Uncertainties on the cosmological observable

$\Delta C_{\ell}^{XY}$

Observation

Noise, beam, partial sky coverage

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Two fiducial experiments

Small scale survey

Observed sky fraction = 1%
Beam = 8 arcmin
Noise = 5.75 uK-arcmin

Large scale survey

Observed sky fraction = 71%
Beam = 8 arcmin
Noise = 2.2 uK-arcmin
Physics of the primordial universe

1. Energy scale of inflation r detection

2. Parity Violation δ detection
Model

$r$

$\Delta r$

$C_{\ell}^{BB}(r) = \frac{r}{r_0} C_{\ell}^{BB}(r_0)$

- Mode Counting
- Pure method

$\Delta C_{\ell}^{BB}$

Fisher matrix

Observation

Noise, beam, partial sky coverage

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Small scale survey

\[ r \geq 10^{-1} \] at \( 3\sigma \)

Large scale survey

\[ r \geq 10^{-3} \] at \( 3\sigma \)

Ferté, Peloton et al. *in prep for PRD*
1. Energy scale of inflation $r$ detection

2. Parity Violation $\delta$ detection
Standard model:

\[ P^T(k) \rightarrow r \rightarrow C^E_B \]

If parity breaking:

\[ P^T_{\text{right}}(k) + P^T_{\text{left}}(k) \rightarrow r_+ \rightarrow C^{BB}_E \]

\[ P^T_{\text{right}}(k) - P^T_{\text{left}}(k) \rightarrow r_- \rightarrow C^{TB/EB}_E \]

Parity violation level: \[ \delta = \frac{r_-}{r_+} \]
Model

\[ \delta \]

\[ \Delta \delta \]

Modified CLASS code

\[ C_{\ell}^{TB}, C_{\ell}^{EB}, C_{\ell}^{BB} \]

- Mode Counting
- Pure method

\[ \Delta C_{\ell}^{TB}, \Delta C_{\ell}^{EB}, \Delta C_{\ell}^{BB} \]

Noise, beam, partial sky coverage

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TB and EB power spectra
Uncertainties on TB and EB

From Ferté & Grain, *PRD* (2014)

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Parity breaking detection

Small scale survey: not possible

Satellite like mission:

<table>
<thead>
<tr>
<th>$r(+) = 0.2$</th>
<th>$\delta = 1$</th>
<th>$\delta = 0.5$</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>5.46</td>
<td>2.5</td>
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<tr>
<td>$r(+) = 0.1$</td>
<td>3.67</td>
<td>1.51</td>
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<tr>
<td>$r(+) = 0.05$</td>
<td>2.35</td>
<td>1.11</td>
</tr>
</tbody>
</table>

$\delta$

$F_+ = 0.005$

signal to noise ratio

$r_+$

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To take away

- CMB polarised anisotropies enables an exploration of the physics of the primordial universe;
- Pure pseudospectrum: efficient B modes estimation;
- $r \geq 10^{-3}$ for potential satellite, $r \geq 10^{-1}$ for suborbital experiments;
- Chiral gravity can only be detected by a satellite experiment.