Constraints on Chiral Gravity

through CMB polarisation

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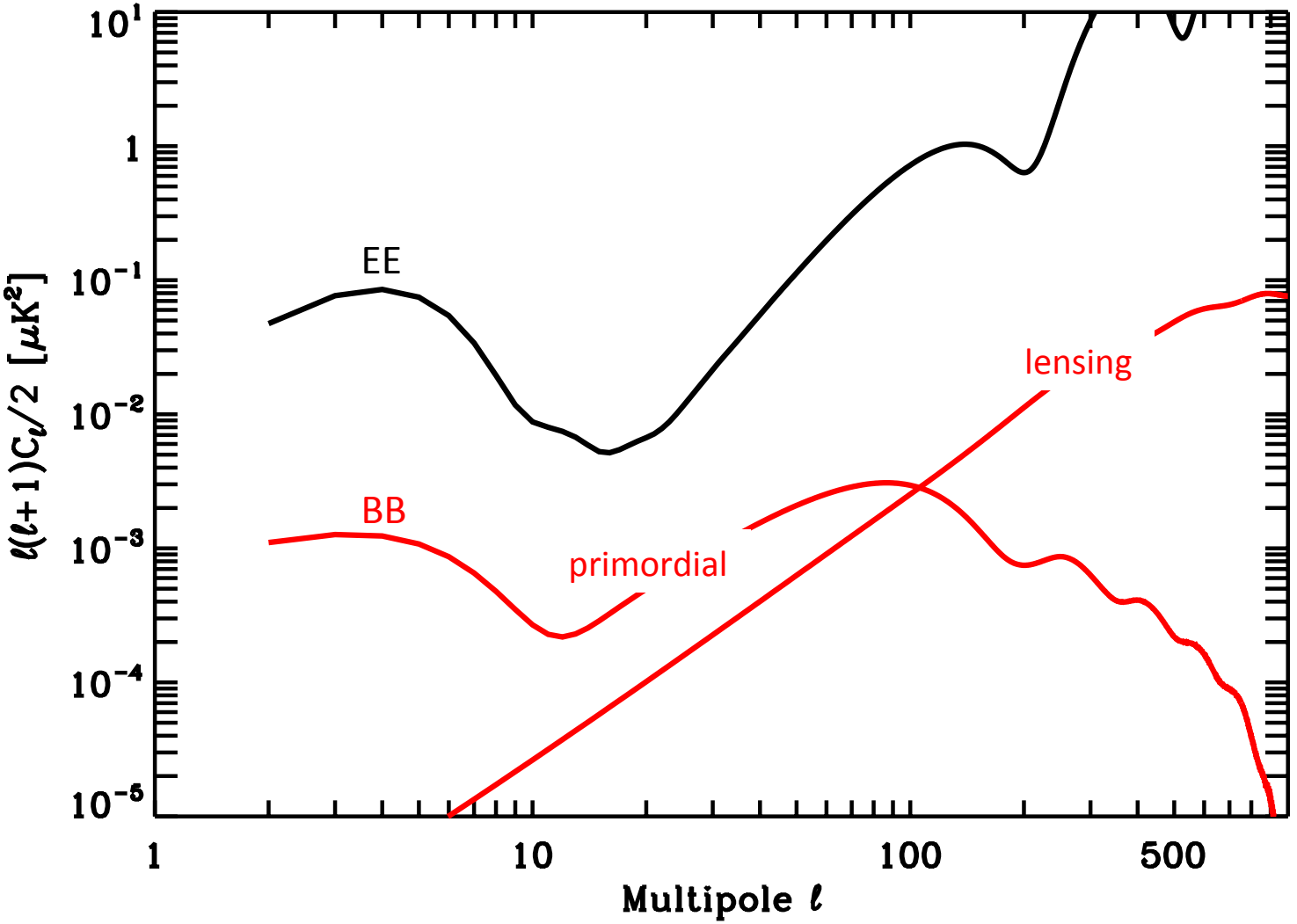
Work with Julien Grain, Radek Stompor, Julien Peloton

http://arxiv.org/abs/1404.6660

1. CMB Polarisation
   Probe of the primordial universe

2. Detectability of Parity Violation
   Detectability of Barbero-Immirzi parameter

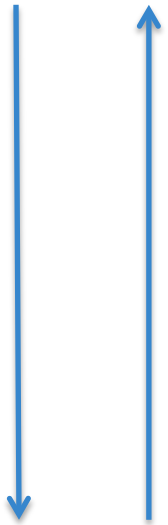
CMB Polarised Anisotropies



MODEL

Primordial Universe

Parameter and constraints



Cosmological observables with **uncertainties**

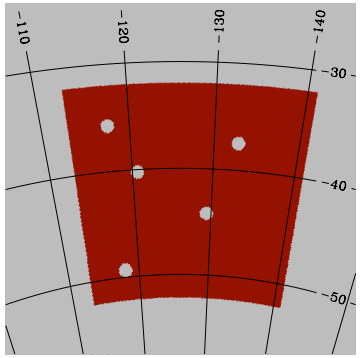
CMB Polarisation

OBSERVATION

Instrumental effects: two fiducial experiments

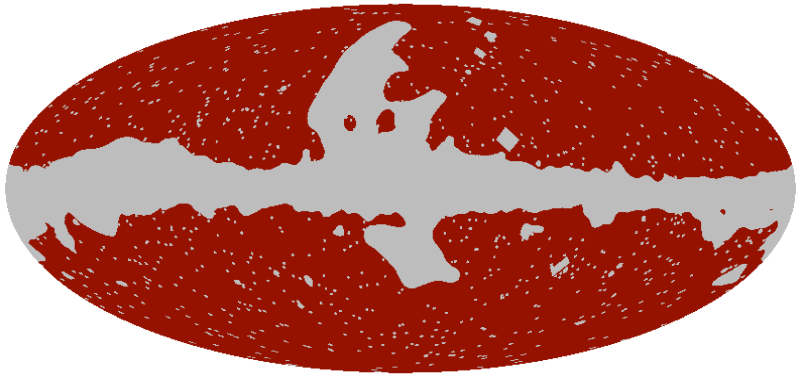
Small scale survey

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



Uncertainties: mode counting expression of sampling variance

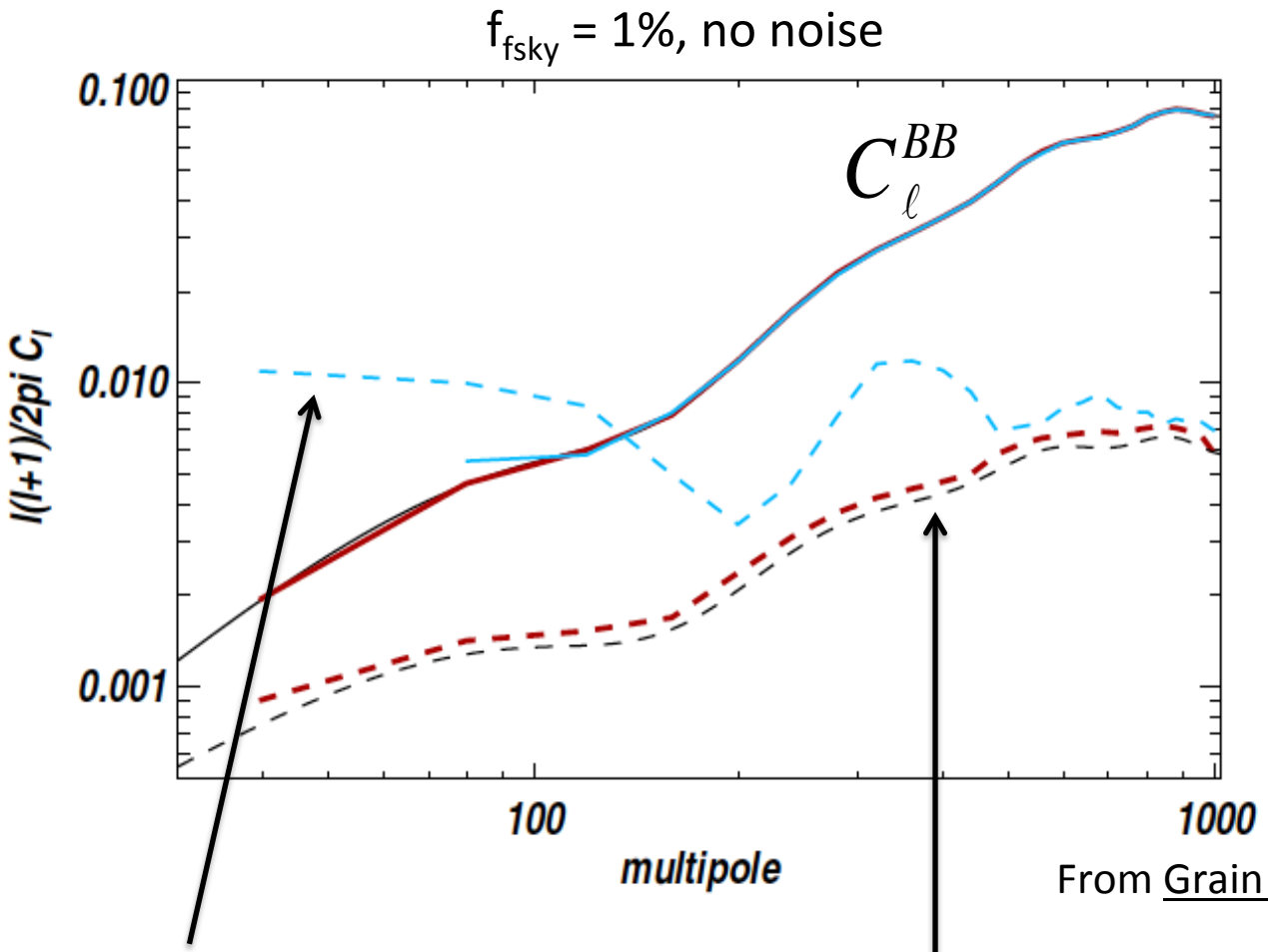
Cosmic (inherent) variance including instrumental effects.

Use of an **analytic formula**. Exemple for the B modes power spectrum:

$$Var(C_\ell^{BB}) = \frac{2}{(2\ell+1) f_{sky}} (C_\ell^{BB} + \frac{N_\ell^{BB}}{B_\ell^2})^2$$

But neglect crucial statistical issues.

B-modes estimation on a partial sky: the E-to-B leakage

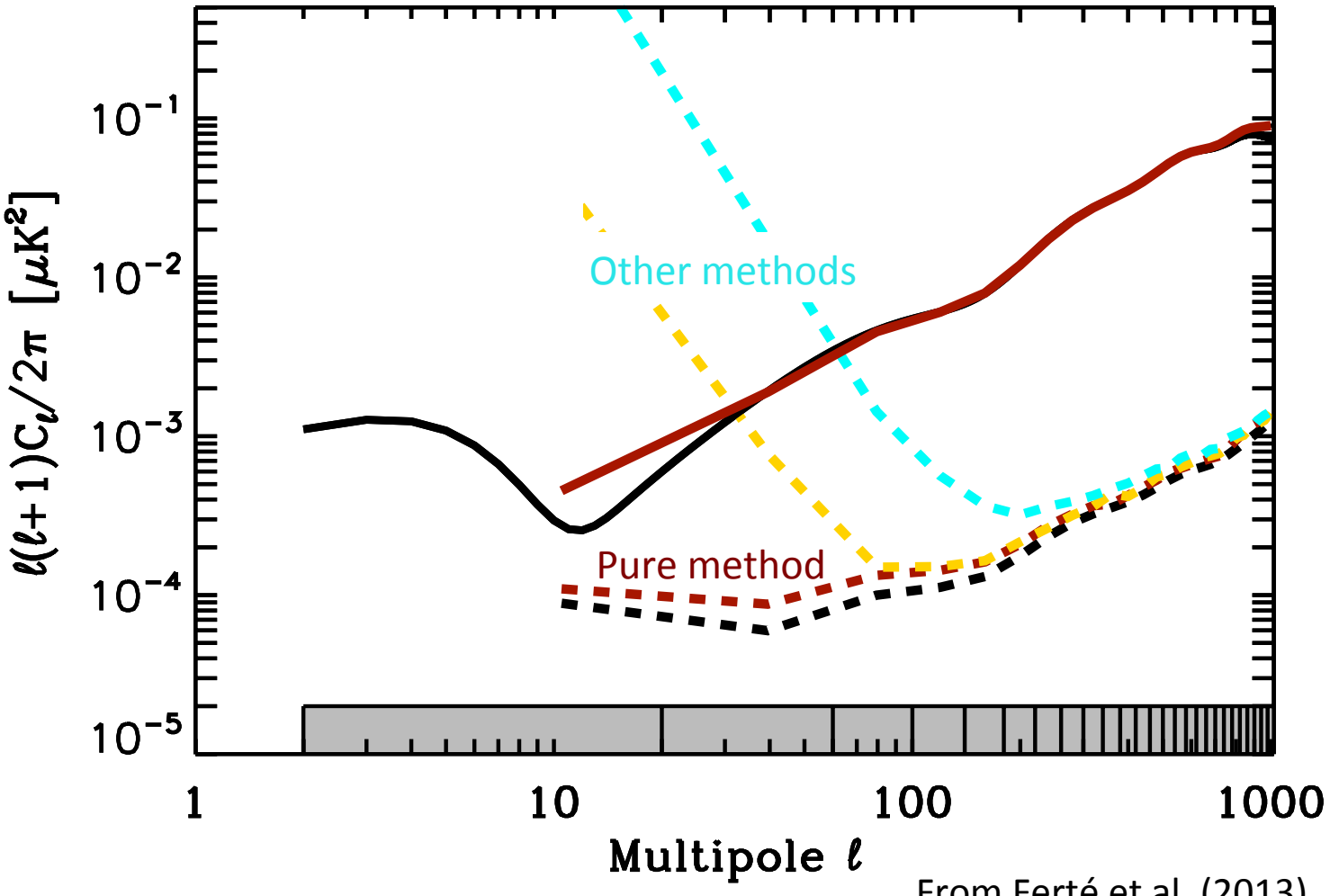


From Grain et al. (2009)

Variance **higher** than the signal.

Mode counting variance

Efficient B-modes estimation: the pure method

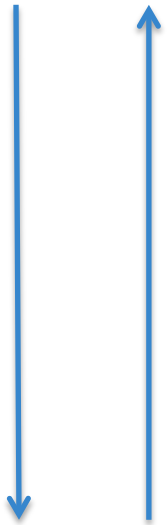


From Ferté et al. (2013)

MODEL

Primordial Universe

Parameter and constraints



Computations with
CLASS code

Fisher analysis

- Mode counting formula;
- Pure estimation;

in case of 2 fiducial experiments

Cosmological observables with **uncertainties**

CMB Polarisation

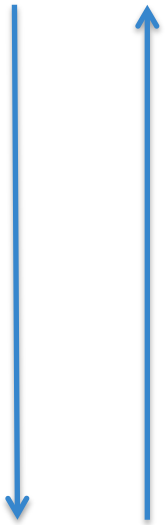
OBSERVATION

Example: constraining energy level of inflation

MODEL

Tensor-to-scalar ratio r

Parameter and constrains



Cosmological observables with **uncertainties**

CMB B-modes

OBSERVATION

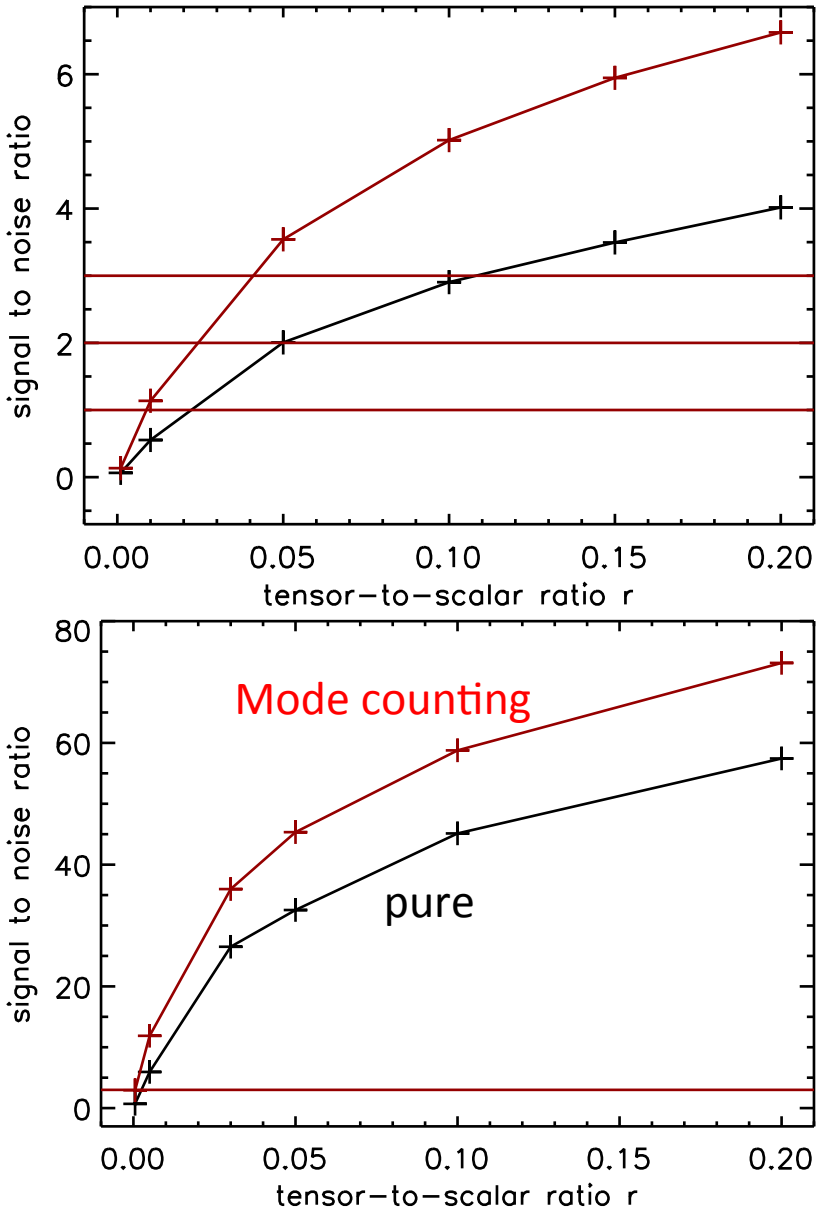
Results: forecasts for tensor-to-scalar ratio detection

Small scale experiment

$r \geq 10^{-1}$ at 3σ

Large scale experiment

$r \geq 10^{-3}$ at 3σ



From Ferté, Peloton et al., in prep. for PRD

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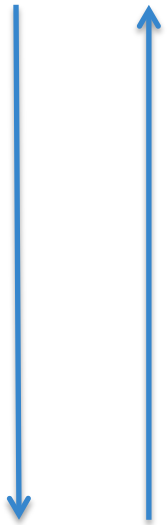
MODEL

Parity Violation on primordial gravitational waves

Parameter and constrains



Cosmological observables with **uncertainties**

TB and EB correlations

OBSERVATION

Parity violation ➔ CMB TB and EB correlations

In parity invariant universe:

$$P^T(k) \longrightarrow C_\ell^{BB} \propto r$$

$$C_\ell^{TB/EB} = 0$$

If parity breaking during inflation:

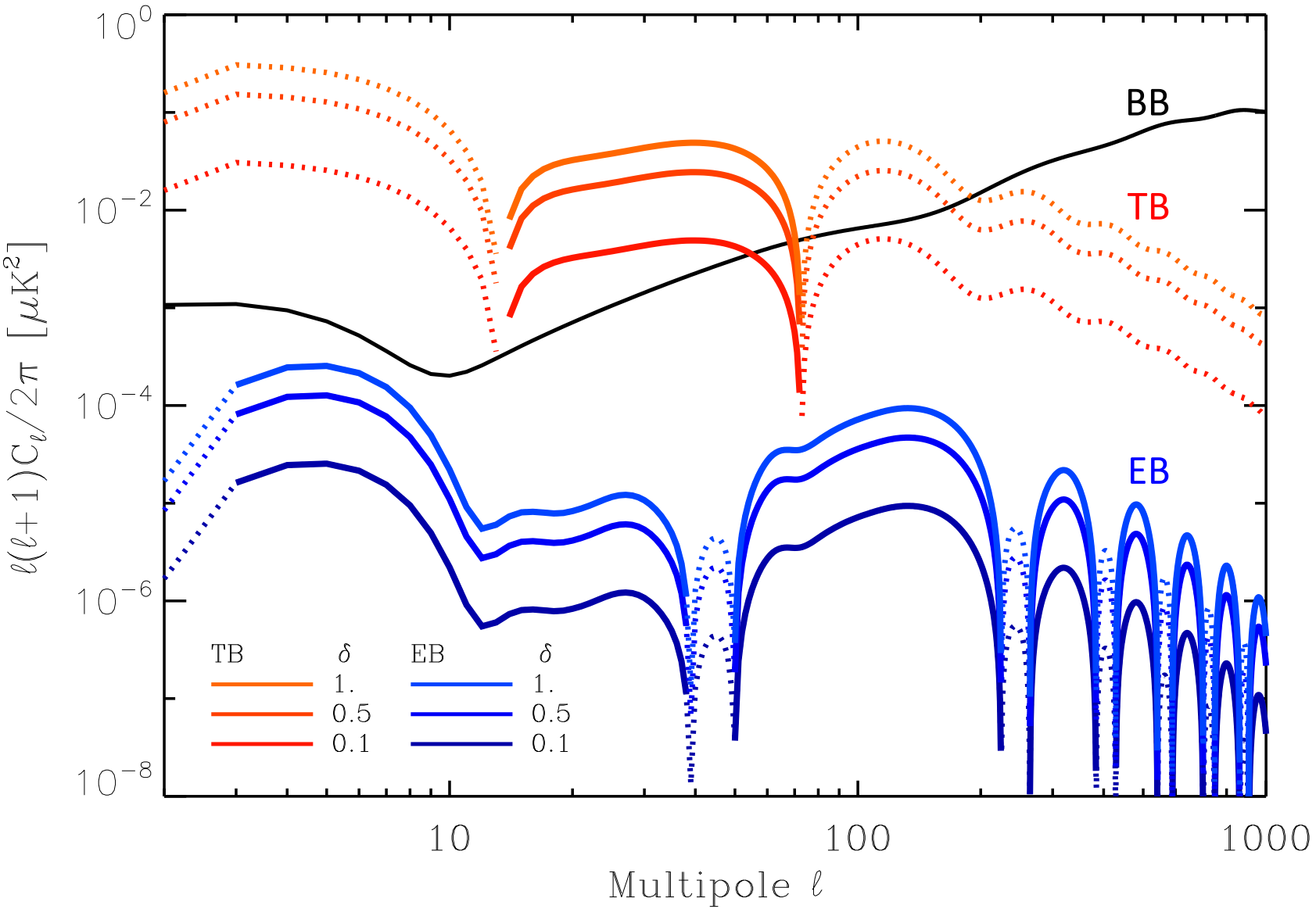
$$P^T_{right}(k) + P^T_{left}(k) \longrightarrow C_\ell^{BB} \propto r_+$$

$$P^T_{right}(k) - P^T_{left}(k) \longrightarrow C_\ell^{TB}, C_\ell^{EB} \propto r_-$$

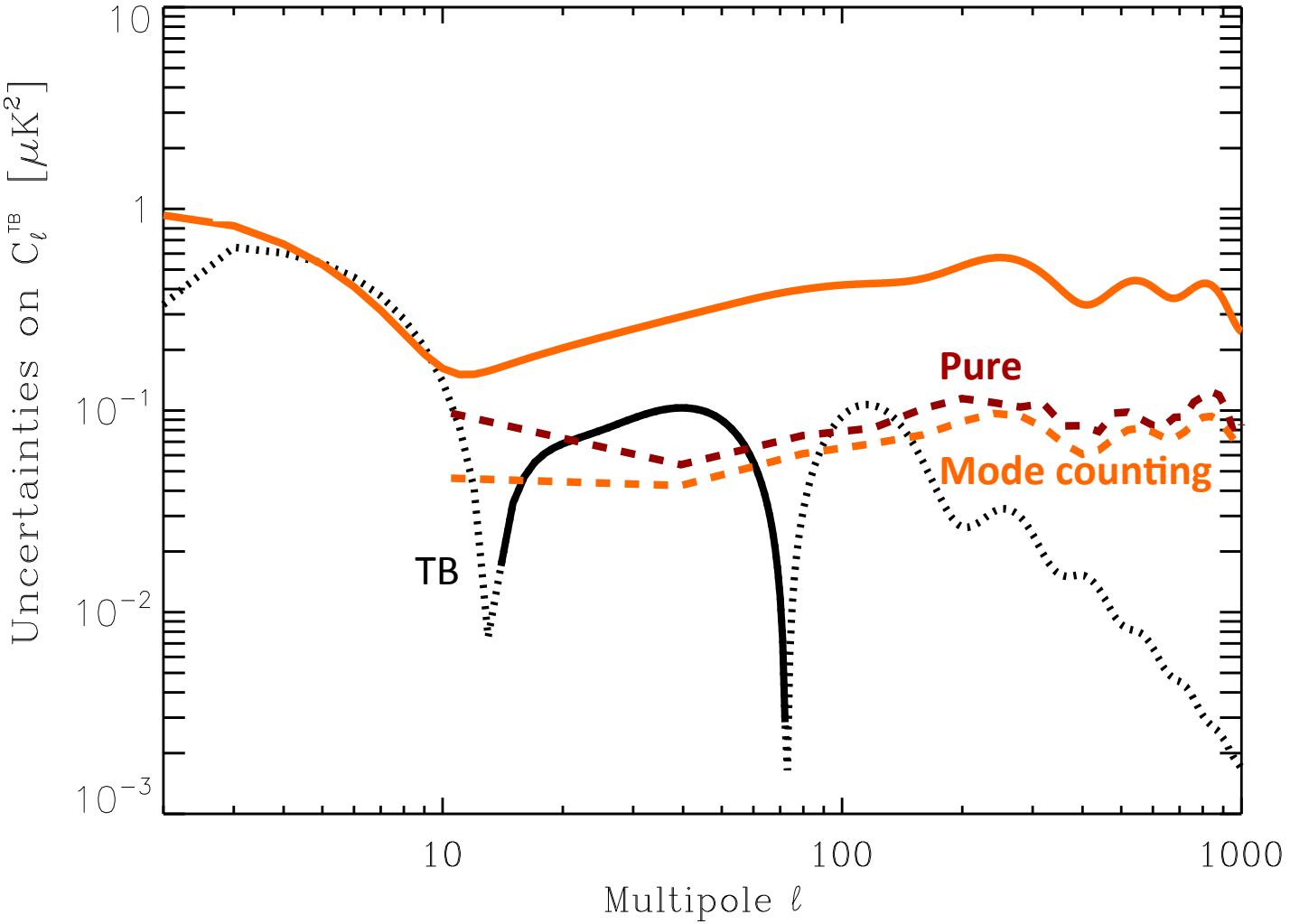
Parity violation level: $\delta = \frac{r_-}{r_+}$

Lue et al, PRL 1999
Alexander, Yunes, Phys Rep 2009
Caprini, Sorbo, arxiv:1407.2809
Contaldi et al, PRL 2008

TB and EB power spectra



Mode counting and pure uncertainties

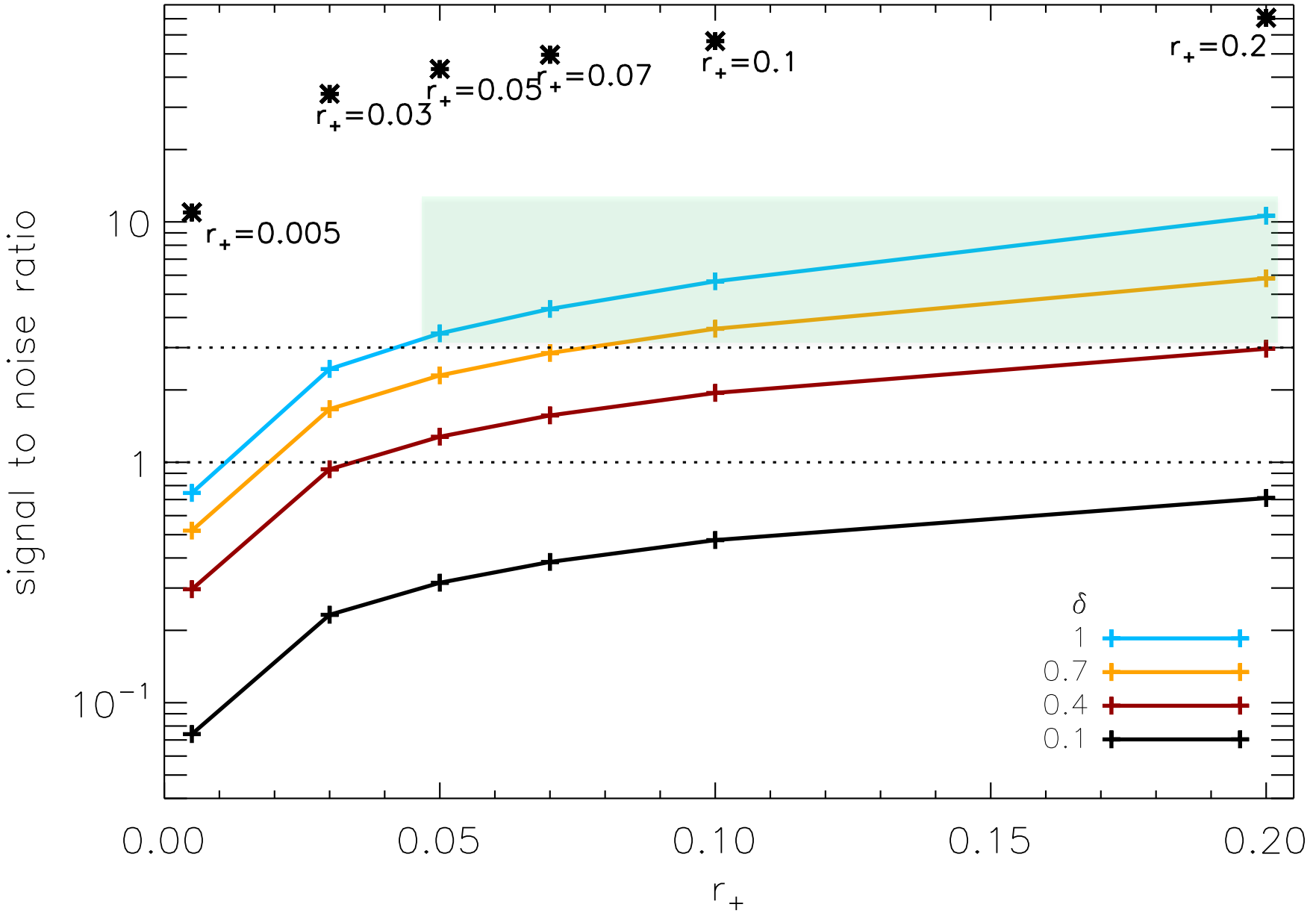


Forecasts: **impossible** to detect with small experiment

For 100% parity breaking and r = 0.2:
SNR = 1.2 using mode counting.

If EB and TB correlations = 0, no constraints on parity breaking.

Forecasts: range of model detectable with satellite experiment



Forecasts: range of model detectable with satellite experiment

With the pure estimation of B-modes:

	$\delta = 1$	$\delta = 0.5$
$r_{(+)} = 0.2$	5.46	2.5
$r_{(+)} = 0.1$	3.67	1.51
$r_{(+)} = 0.05$	2.35	1.11

Instrumental effects can cause EB and TB correlations

Miscalibration angle of 0.1 degree: SNR = 5 for $r_+ = r_- = 0.2$;
SNR = 2.96 for $r_+ = r_- = 0.1$.

Miscalibration angle of 1 degree: SNR = 2.23 for $r_+ = r_- = 0.2$;
SNR = 1.58 for $r_+ = r_- = 0.1$.

EB and TB correlations have to be **very well modeled**.

Achievable Constraints on the Barbero-Immirzi Parameter

$$\delta = \frac{2i\gamma}{(1-\gamma^2)}$$

$|\gamma| = 1$: r = 0.05, SNR = 2.3
r = 0.2, SNR = 5.4

$0.26 \leq |\gamma| \leq 3.75$: r = 0.2, SNR ≥ 2.5

EB, TB consistent with zero: $0.66 \leq |\gamma| \leq 1.5$ excluded at 3σ for $r_+ = 0.05$

$0.2 \leq |\gamma| \leq 4.9$ excluded at 3σ for $r_+ = 0.2$

Contaldi et al, PRL 2008
Magueijo, Benincasa, PRL 2011
Bethke, Magueijo, PRD 2011
Bethke, Magueijo, CQG 2012

To take away

- The **CMB polarisation** is a powerful observable of physics of the primordial universe.
- Range of values for Barbero-Immirzi parameter achievable with **a future satellite** experiment.
- For this purpose, the CMB polarisation has to be known **very well** modeled and the instrument fully understood.

@CosmoloGirl
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