Constraining cosmic defects with CMB

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I. Inflation and Defects

- INFLATION is the main source of inhomogeneities
- But many physically motivated inflation models produce DEFECTS: including **(SUSY) hybrid inflation**, and **string/brane theory**
- Is there room in the CMB data for INFLATION+DEFECTS?
- Different types defects: cosmics strings, semilocal strings, textures [1]

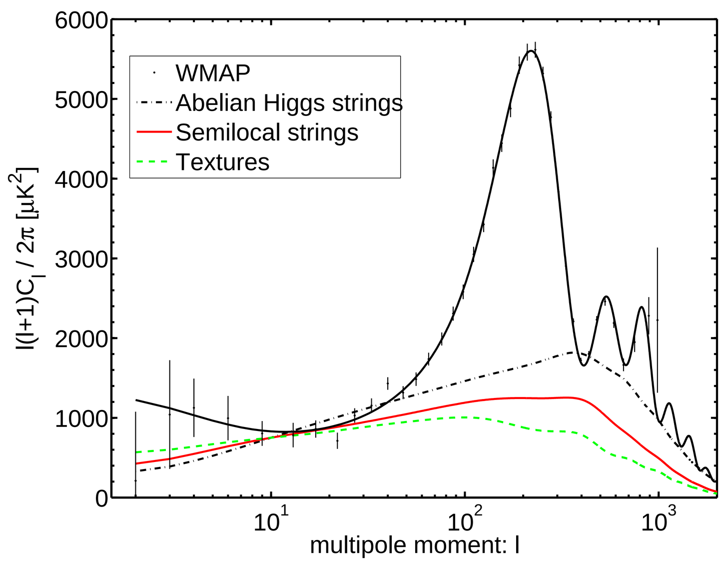


FIGURE 1: The CMB temperature power spectrum for inflation, cosmic strings, semilocal strings and textures.

II. CMB predictions for strings: field theoretical numerical simulations

Simulate local cosmic string networks ⇒ solve Abelian Higgs model on a cubic box with periodic boundary conditions

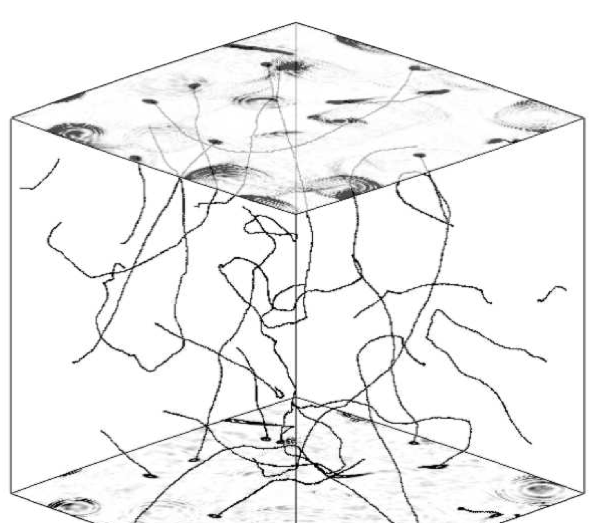
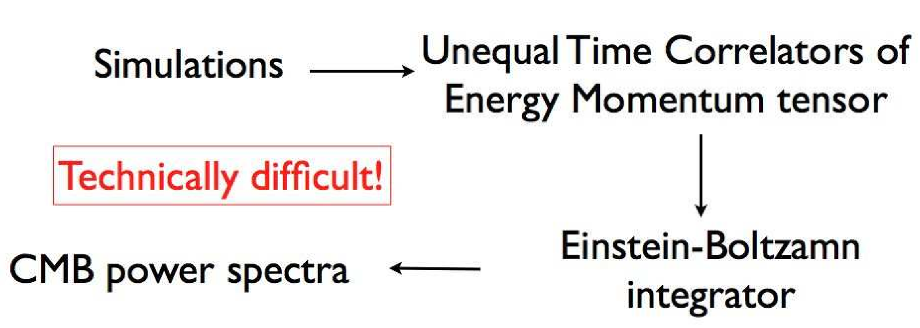


FIGURE 2: A snapshot from an Abelian Higgs simulation.



NEW: We have improved our older results [2]→ [3].
Now accurate predictions for $\ell = 2 \to 4000$.
At high ℓ the spectrum decays initially as $1/\ell^2$, but then slows to $1/\ell$ for $\ell \gtrsim 3000$.

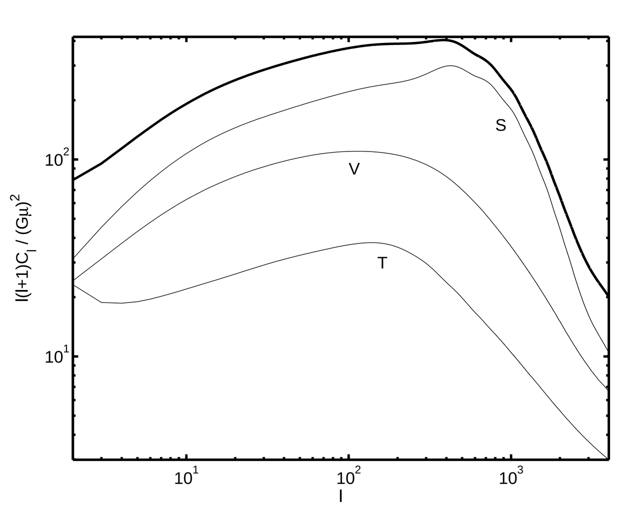


FIGURE 3: The **new** CMB temperature power spectrum, showing the total (thick line) plus the decomposition into scalar (S), vector (V) and tensor (T) modes.

III. Fitting inflation and strings to the CMB data [WMAP]

- Strings and inflation added in **quadrature**
- Multiparameter likelihood analysis:
  Usual 6 parameters (Ω_b, Ω_c, θ, τ, n_s, A_s) plus strings
- Strings characterized by $G\mu$ or f_{10}:
  $G\mu \to$ string tension and symmetry breaking scale
  $f_{10} \to$ fractional contribution to temperature spectrum at $\ell = 10$
  $f_{10} \propto (G\mu)^2$

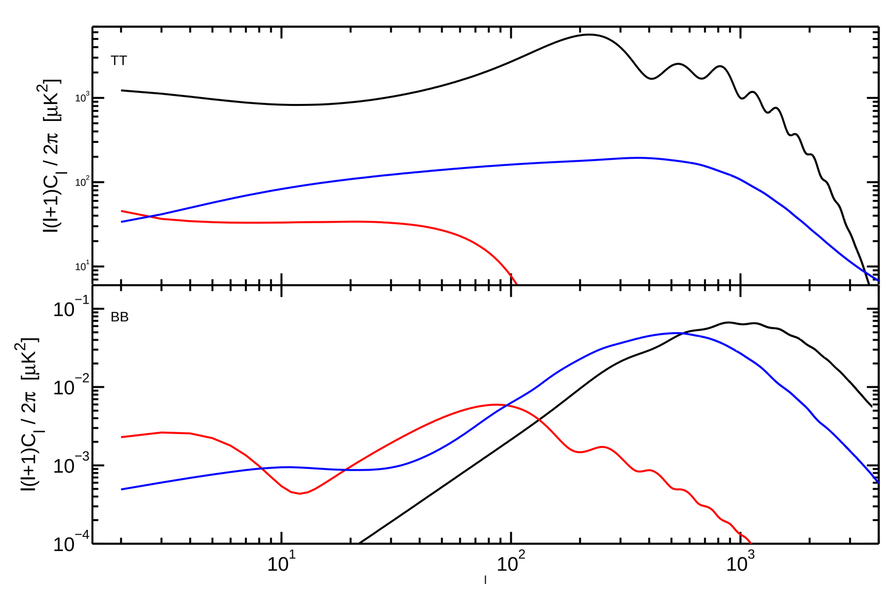


FIGURE 4: Adiabatic scalar contribution from inflation, string contribution and tensor contribution. $f_{10} \approx 0.1$, $r \approx 0.04$

Old result [4]: with WMAP 3-year data release, best-fit model was a model with spectral index $n_s = 1$ and $f_{10} = 0.11 \pm 0.05$

Important: strings make a strong B-mode polarization contribution [5]

NEW: Analized new data (WMAP7+CBI09 + ACBAR) with new string spectra. Considered standard ΛCDM model (PL), with strings (AH) and including Sunyaev-Zel'dovich effect (SZ).
95% upper bounds obtained [6]:

Data	CMB data only			
Model	PL	PL + AH	PL + SZ	PL + SZ + AH
n_s	0.990	1.014	0.987	1.001
$\ln(10^{10}A_s)$	3.13	3.12	3.13	3.12
A_{SZ}	-	-	2.1	1.9
$10^6(G\mu)$	-	0.55	-	0.50
f_{10}	–	0.088	–	0.069

IV. Strings or tensors? [Planck]

Primordial tensors and cosmic defects → strong B-mode signals
If some 'extra' ingredient detected, can cosmic strings be mistaken for primordial tensors?

Simulated Planck data varying primordial tensors r and cosmic strings f_{10}:

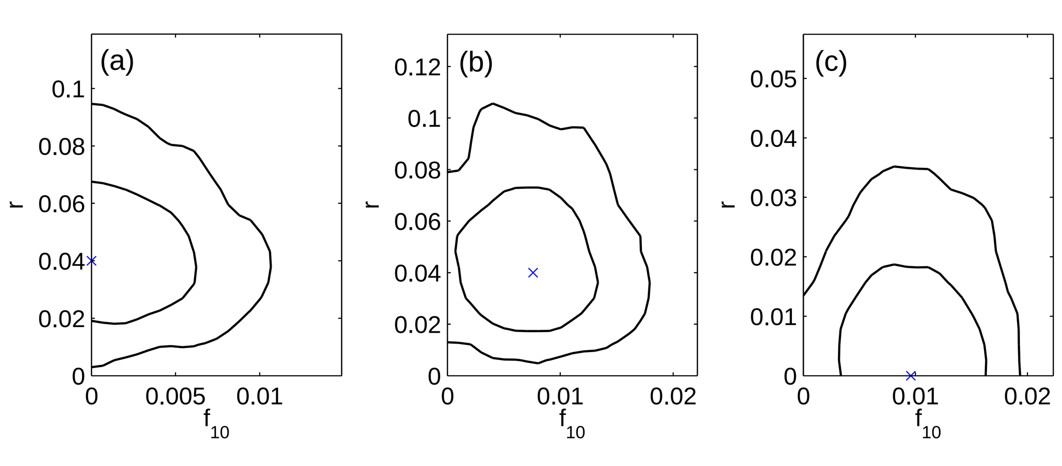


FIGURE 5: 68% and 95% contours of the marginalized 2D posterior for cosmological models with: (a) $r = 0.04$ and no strings, (b) $r = 0.04$ and $f_{10} = 0.008$, and (c) no tensors and $f_{10} = 0.01$

Fitting cosmologies with correct parameters very successful. When fitting with the wrong parameters, one detection will not be mistaken for another, so:

If Planck detects some extra ingredients in the B-mode polarization spectra, its accuracy is enough to say whether the source are primordial tensor modes or cosmic defects [7].

Fitting for	Mean	Stand. Dev.	68% Upper Bound	95% Upper Bound
f_{10} only	0.0043	0.0029	0.0056	0.0098
f_{10} and r	0.0033	0.0026	0.0041	0.0084
r only	0.012	0.010	0.015	0.033
r and f_{10}	0.011	0.0091	0.013	0.029

TABLE 1: First two rows: Values of f_{10} obtained when trying to fit a fiducial model with tensors $r = 0.04$ and no strings. Last two rows: Values of r when trying to fit a fiducial model with strings with $f_{10} = 0.01$ and no tensors.

V. Distinguishing defects [(CM)Bpol]

The CMBPol mission can go one step further from Planck.
Can the satellite distinguish between these different types of defects?
What is the detection threshold for cosmic strings and for textures?
Strategy:

- Simulate CMBPol data in its high-resolution version
- Fiducial model: flat ΛCDM plus some cosmic strings or some textures
- Fit simulated data with different models: a model with strings; a model with textures; and combinations of them

Model has	δf_{10}^{st}	δf_{10}^{tex}	δr
Str	0.00041	–	–
Str	–	0.00015	–
Str	–	–	0.00052
Str	0.00056	0.00026*	–
Str	0.00055	0.00025*	0.00055*

TABLE 2: Standard deviation achieved when trying to fit the data with a model with one, two or three extra components.The fiducial value is $f_{10}^{st} = 0.002$. The stars (*) denote the cases when only upper limits are placed and the numbers quoted are the difference between the 68% and 95% upper limits.

The level of defects that can be detected and correctly identified at 3σ by CMBPol is $f_{10}^{st} = 0.002$ and $f_{10}^{tex} = 0.001$.
Contributions from strings and textures are highly correlated. At lower levels it would be harder to attribute the signal to one or the other conclusively [8].

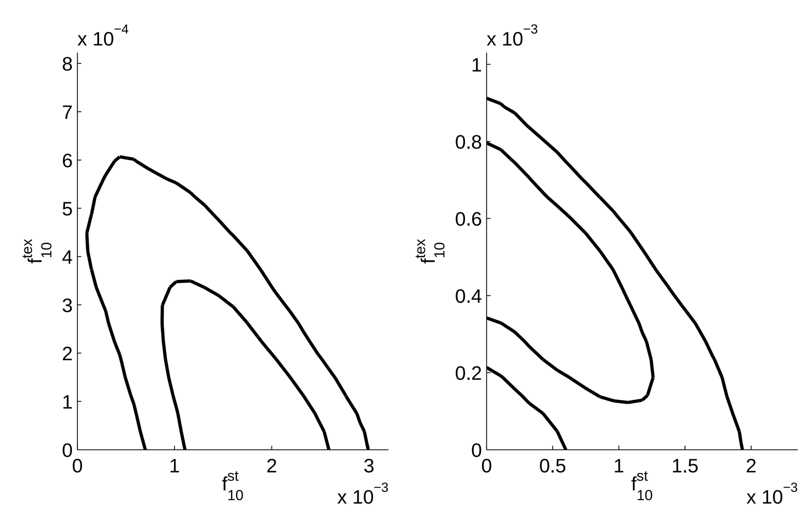


FIGURE 6: The correlation between strings and textures in simulated CMBPol data with strings (left panel) and textures (right panel), showing 68% and 95% confidence contours.

Model selection will help. In this case strings is the right model:

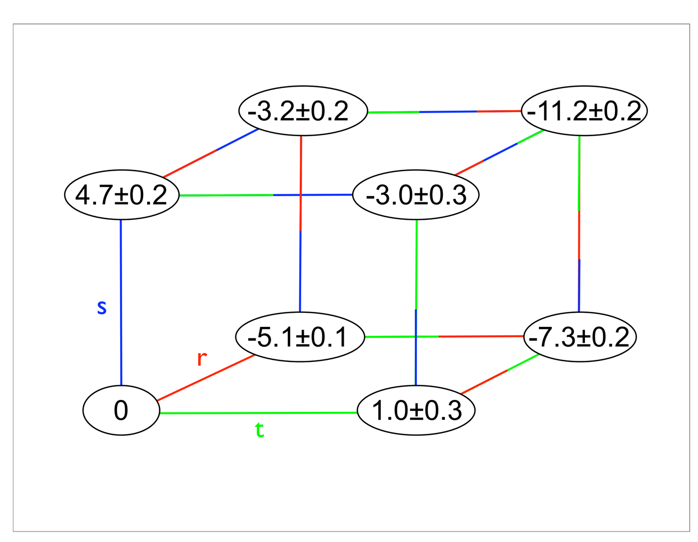


FIGURE 7: Pictorial representation of the logarithm of the Bayes factors for different models, relative to a model with 'no defect'. The lower left corner of the cube corresponds to the 'no defect' model, and each of the axis of the cube corresponds to 'adding' strings (s), textures (t) or tensors (r).

References

[1] J. Urrestilla, N. Bevis, M. Hindmarsh, M. Kunz, A.R. Liddle, JCAP **0807** (2008) 010
[2] N. Bevis, M. Hindmarsh, M. Kunz, J. Urrestilla, Phys. Rev. D **75** (2007) 065015
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[4] N. Bevis, M. Hindmarsh, M. Kunz, J. Urrestilla, Phys. Rev. Lett. **100** (2008) 021301
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