FERMILAB-POSTER-21-079-E-STUDENT

Searching for Cosmic Strings Using SPT-3G data

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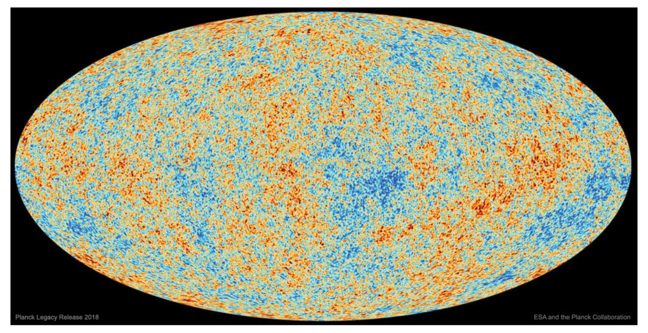
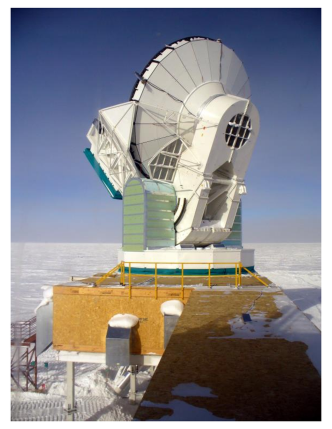
Background

The CMB is the oldest light in the universe, and it provides information about the universe 380,000 years after the big bang. The CMB light is observed using microwave telescopes such as the **South Pole Telescope (SPT)** or satellites such as **Planck.**



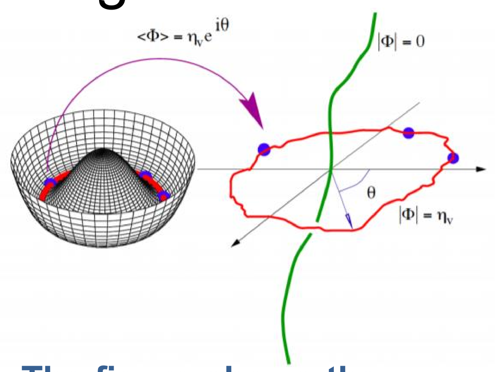
A Map of the CMB anisotropies of the full sky by Planck.



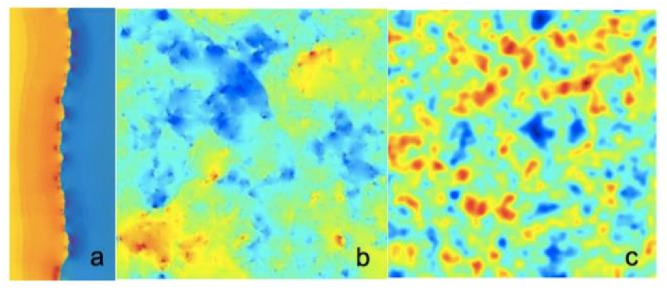
Picture of SPT taken in November 2011.

Cosmic Strings

Cosmic Strings are linear topological defects which possibly contribute to the fluctuations (anisotropies) of the CMB. Cosmic strings have not been detected before, and they could provide indications of a certain beyond-standard-model theory. There are several ways to look for Cosmic strings including, using their power spectrum or edge-detection algorithms.



The figure shows the transformation of the ground state in a certain potential in field space to physical space. When the ground state cannot be mapped to a line in physical space, a linear topological defect occurs.



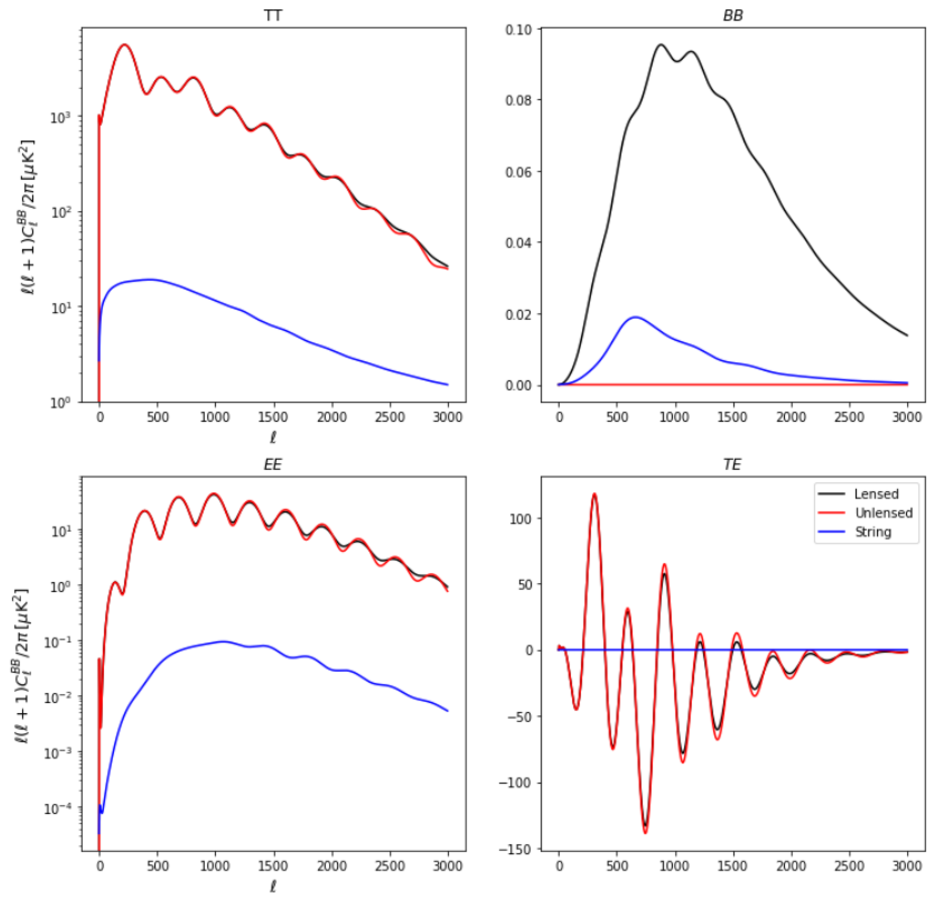
a) a line-discontinuity in CMB temperature caused by a single string on a uniform background (image provided by Proty Wu and Paul Shellard, (J.H.P.Wu PhD thesis, U. of Cambridge, 2000)). b) anisotropy caused by a network of strings alone (0708.1162). c) anisotropy caused by a network of strings with CMB anisotropy (1004.2885) .

Research Question and Motivation

We are trying to estimate the sensitivity of SPT in detecting cosmic strings. In 2013, the Planck collaboration published their strings analysis and their constraints on the string tension Gμ. SPT has a better sensitivity for polarized CMB compared to Planck, so the question becomes **is SPT more sensitive to Strings than Planck?**

Methods

Power Spectrum of primary CMB was simulated using CAMB (a python package). The string model was obtained using CMBACT (a Fortran code that calculates the power spectrum of strings in accordance with a certain string model.



The figure shows the power spectrum of the primary CMB and strings from CAMB and CMBACT respectively.

Fisher Forecast

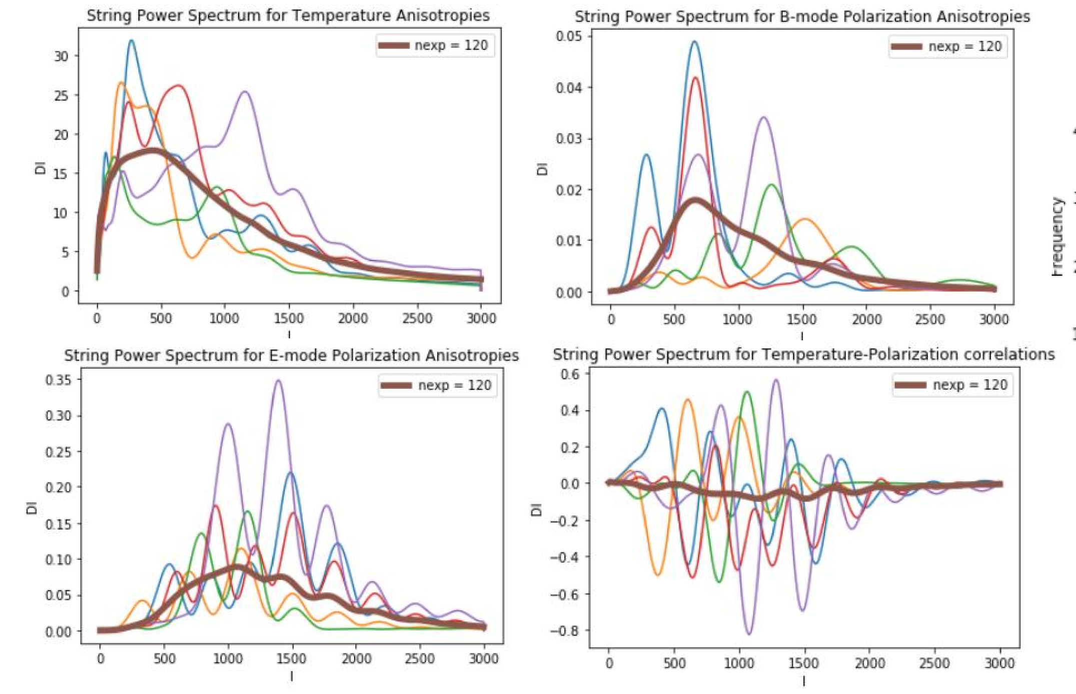
Fisher Forecast has the following formalism. It is used to calculate uncertainties on cosmological parameters such as string tension Gμ.

$$F_{ij} = \sum_{\ell} \frac{2\ell+1}{2} f_{sky} \mathrm{Tr}\left(C_\ell^{-1}(\theta) \frac{\partial C_\ell}{\partial \theta_i} C_\ell^{-1}(\theta) \frac{\partial C_\ell}{\partial \theta_j} \right)$$

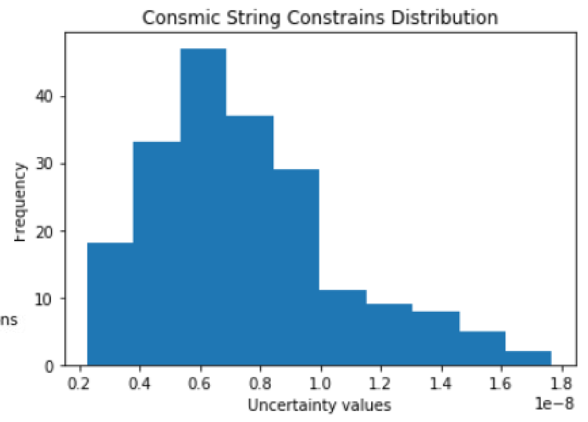
$$C_\ell \equiv \begin{pmatrix} C_\ell^{TT} + N_\ell^{TT} & C_\ell^{TE} & 0 \\ C_\ell^{TE} & C_\ell^{EE} + N_\ell^{EE} & 0 \\ 0 & 0 & C_\ell^{BB} + N_\ell^{BB} \end{pmatrix}$$

$$\sigma_i \equiv \sigma(\theta_i) = \sqrt{(\mathbf{F}^{-1})_{ii}}$$

String Realizations and Distribution



Single realizations of the string power spectra, and the power spectrum representing the average of 120 distinct realizations. (from CMBACT)

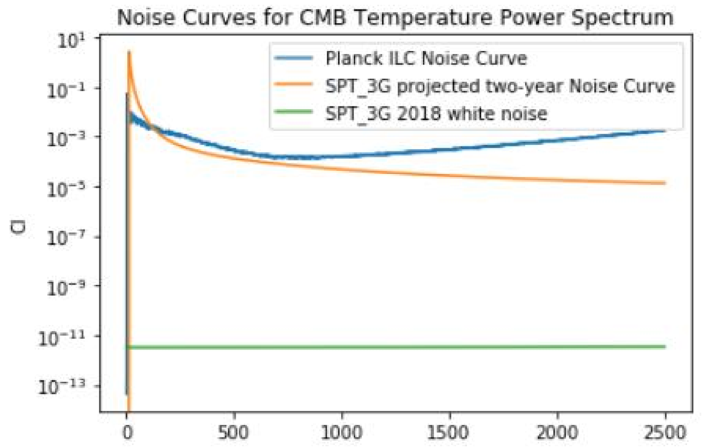


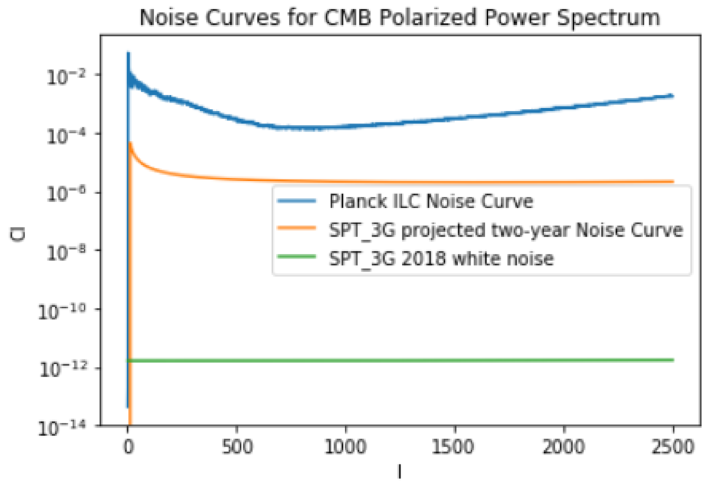
The uncertainty distribution of 200+ distinct string realizations.

Forecasts

Configuration	$\Omega_b h^2$	$\Omega_c h^2$	H_0	τ	ns	As / log(As)	Gμ
Lmax =3000 Lmin = 100 Lensed 2_year noise curves Tau = 0.0070 (prior) Fsky = 1500 / 41253	1.46E-4	2.03E-3	7.68E-1	6.76E-3	7.35E-3	2.72E-11 5.626E-3	No strings
Nexp = 120 Gmu = 10^(-7) Tau = 0.0070 (prior)	1.49E-4	2.13E-3	8.01E-1	6.78E-3	7.43E-3	2.81E-11 5.80E-3	1.12E-8
BB included Nexp = 120 Gmu = 10^(-7) Tau = 0.0070 (prior)	1.44E-4	1.8E-3	6.71E-1	6.78E-3	6.7E-3	2.72E-11 5.62E-3	8.37E-9
Planck Fsky = 0.73	1.12E-4	1.37E-3	5.51E-1	6.77E-3	4.11E-3	2.944E-11 6.09E-3	1.92E-8

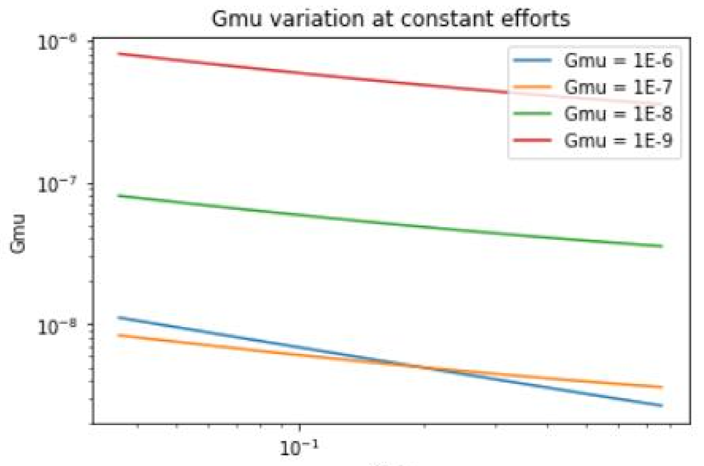
Noise





Noise Curves of different experiments. These curves were used in different configuration of the fisher forecast.

Fsky variation



The uncertainty on Gμ as we increase the observed sky fraction.

References

1. Dvorkin, Cora, Mark Wyman, and Wayne Hu. "Cosmic String Constraints from WMAP and the South Pole Telescope Data." Physical Review D 84.12 (2011): n. pag.
2. Crossref. Web. 4. Ade, P. A. R. et al. "Planck2013 results. XXV. Searches for cosmic strings and other topological defects". Astronomy & Astrophysics 571. (2014): A25.
3. Dan Coe, . "Fisher Matrices and Confidence Ellipses: A Quick-Start Guide and Software." (2009).
4. Wu, W. L. K. et al. "A GUIDE TO DESIGNING FUTURE GROUND-BASED COSMIC MICROWAVE BACKGROUND EXPERIMENTS". The Astrophysical Journal 788. 2(2014).
5. L. Balkenhol, et al. "Constraints on LambdaCDM Extensions from the SPT-3G 2018 EE and TE Power Spectra." (2021).
6. Aghanim, N. et al. "Planck 2018 results". Astronomy & Astrophysics 641. (2020): A6.
7. M. Landriau and E. Shellard, Phys.Rev. D83, 043516 (2011), 1004.2885.
8. A. A. Fraisse, C. Ringeval, D. N. Spergel, and F. R. Bouchet, Phys.Rev. D78, 043535 (2008), 0708.1162.

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