# Got a $B$-modes detection? Better $\boldsymbol{B}$-sure: robustness tests for tensor-to-scalar ratio detection from CMB

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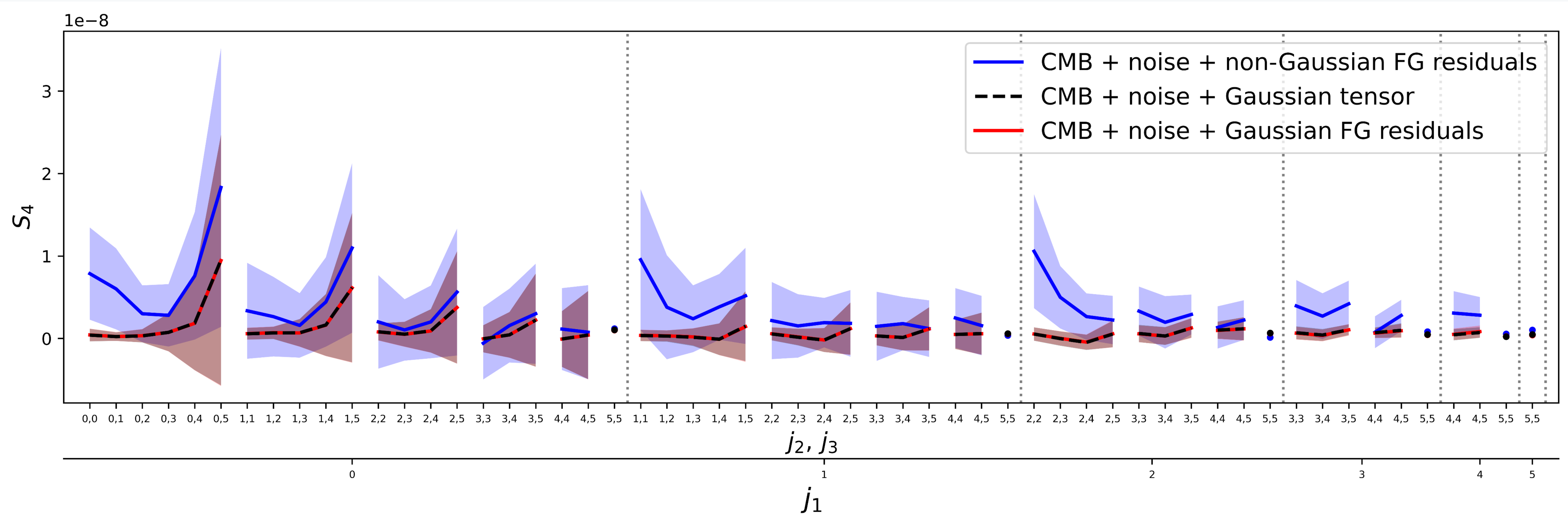
Polarised Galactic **foregrounds** can bias the measurement of the **tensor-to-scalar ratio** $\boldsymbol{r}$. How to avoid a false detection?

We built a **robustness test** based on Scattering Transforms (**ST**): statistical tools sensitive to **non-Gaussian features.**

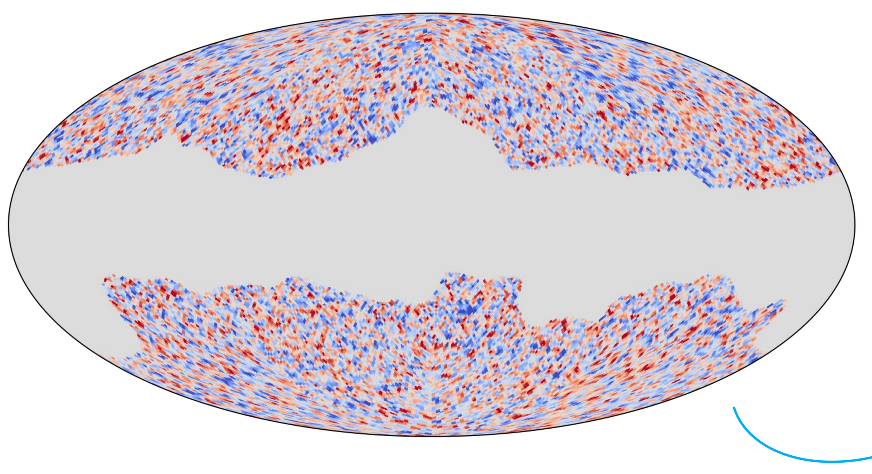



The test can identify a false detection in ~90% of realistic simulations

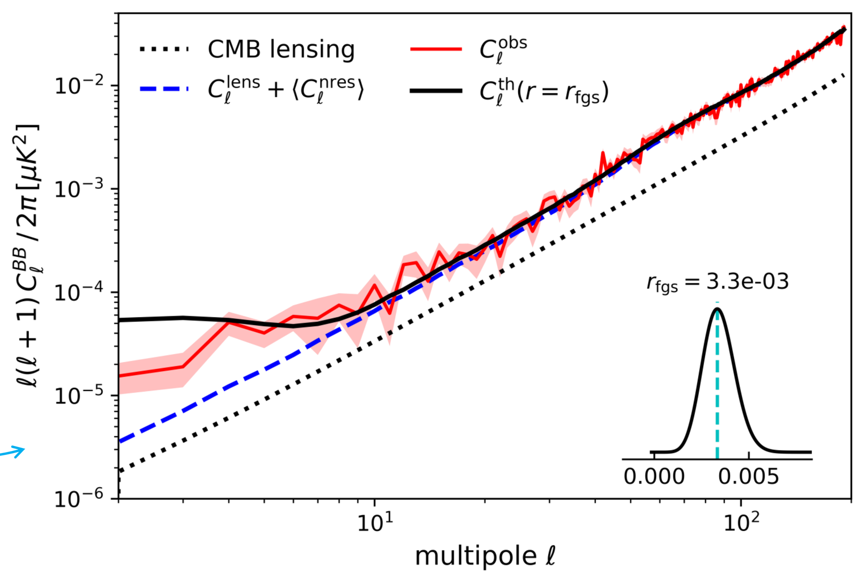
## The problem

Future Cosmic Microwave Background (**CMB**) observatories aim to prove the *inflationary* scenario, by constraining the **tensor-to-scalar ratio** $\boldsymbol{r}$. **Galactic foregrounds** can bias the measurement and induce a **false detection** (aka, the *BICEP* accident). We need robustness tests to validate the detection.

cleaned CMB map



biased power spectrum fit




B-sure I, CR+ 26

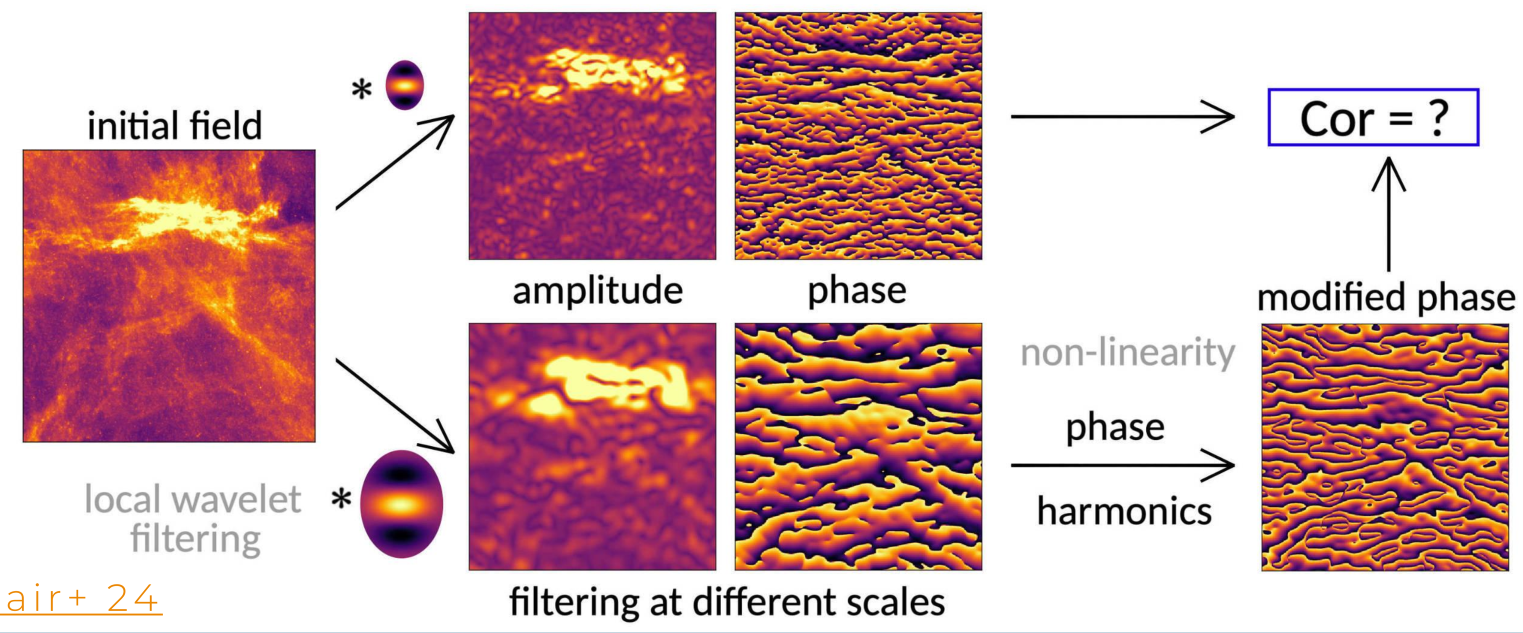
## Scattering Transforms (Mallat 12, Allys+ 19)

Statistics based on **wavelet** transform, where a map is convolved with directional filters. It describes power and sparsity of a field at scales $j$ and orientations $\theta$, plus **scale interactions**.

$$\lambda_i = (j_i, \theta_i) \qquad S_1(\lambda_1) = \langle |I \star \psi^{\lambda_1}| \rangle \qquad S_2(\lambda_1) = \langle |I \star \psi^{\lambda_1}|^2 \rangle$$

$$S_3(\lambda_1, \lambda_2) = \mathrm{Cov}[I \star \psi^{\lambda_1}, |I \star \psi^{\lambda_2}| \star \psi^{\lambda_1}]$$

$$S_4(\lambda_1, \lambda_2, \lambda_3) = \mathrm{Cov}[|I \star \psi^{\lambda_3}| \star \psi^{\lambda_1}, |I \star \psi^{\lambda_2}| \star \psi^{\lambda_1}]$$

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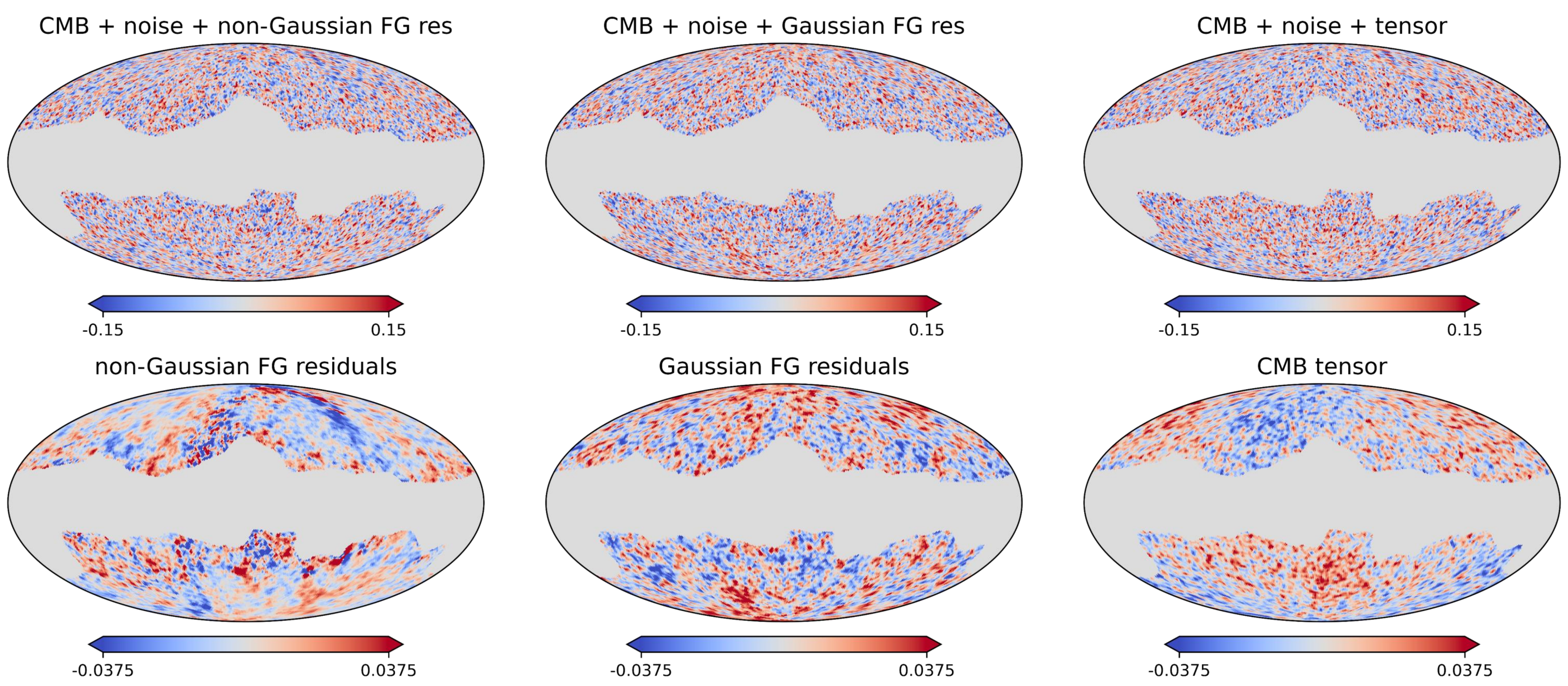
## Experimental setup

We generate realistic, *LiteBIRD*-like sky simulations, and we apply map-based component separation to recover cleaned CMB maps. We measure the tensor-to-scalar ratio, biased by **foreground residuals**.
Then we use this value of $\boldsymbol{r}$ to generate **Gaussian simulations** of tensor perturbations.




## Results

We compare the **WST** coefficients of Gaussian and non-Gaussian maps, auto- and **cross-correlated** with different **tracers**. In case of a **false detection**, the test raises a flag when we correlate with **synchrotron** maps or **foreground residual** estimates. For a **true detection**, the test is passed.

Percentage of identified false detections

| | auto | cross-dust (402 GHz) | cross-synchro (40 GHz) | cross-FG res (ideal) |
|---|---|---|---|---|
| $r_{in}$ = 0, no bias | ~5% | ~5% | ~5% | ~5% |
| $r_{in}$ > 0, no bias | ~5% | ~5% | ~5% | ~5-10% |
| $r_{in}$ = 0, bias | ~50% | ~75% | **~90%** | ~90% |

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