Application of Constraint ILC on Rayleigh signal

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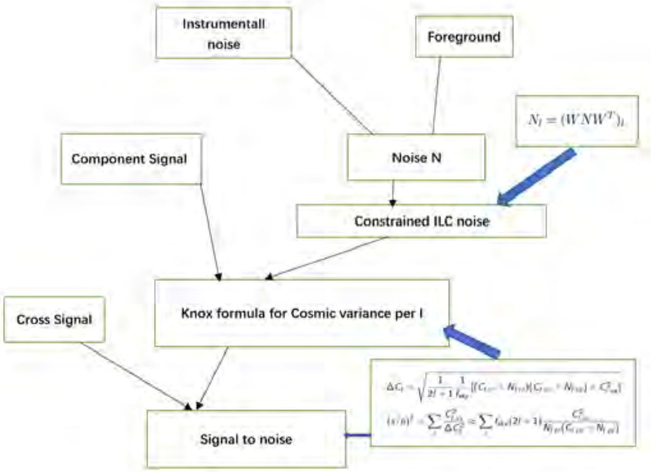
Introduction

In this project, we look at the cross spectra of Rayleigh signal and CMB, and use constrained ILC to upweight one signal and downweight another, in the presence of foreground. We also try to look at the combinations of polarized and unpolarized signal, to see how polarization may help with our observation.
The current experimental setup is a combination of $CCATp$, with undetermined f_{sky}, and $PLANCK$.

Procedure

Calculation procedure



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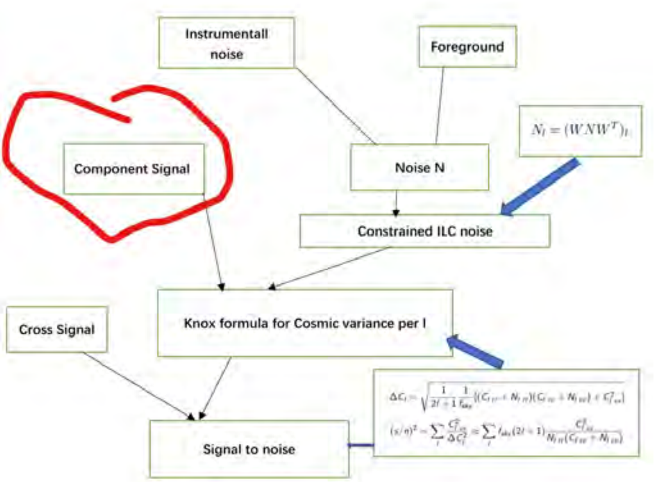
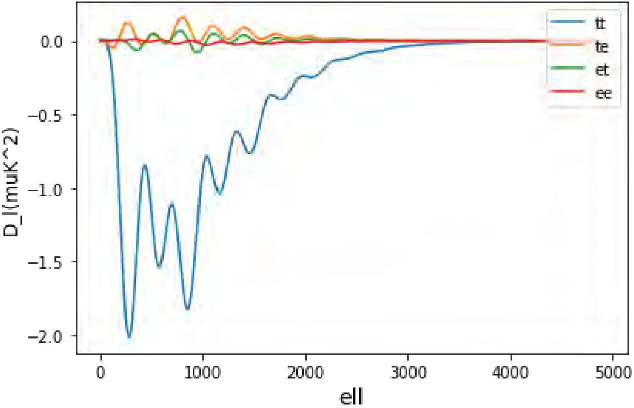


Signal

The signal we are looking for is CMB component cross RS. This is plotted at frequency $280GHz$, with $D_l = T_{CMB}^2 C_l \frac{l(l+1)}{2\pi}$.



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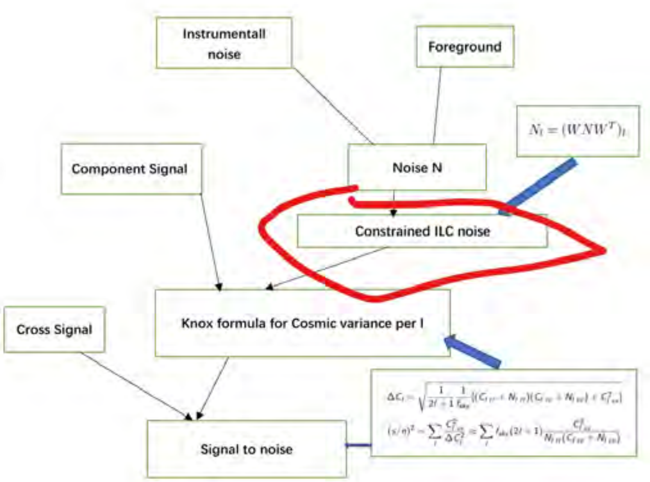


Constrained Weight and Noises

Suppose that we have signals $\vec{a}$ and $\vec{b}$, and covariance matrix N, which encodes noises from each channel, and want to upweight $\vec{a}$ and downweight $\vec{b}$, then

$$W\vec{a} = 1; W\vec{b} = 0$$

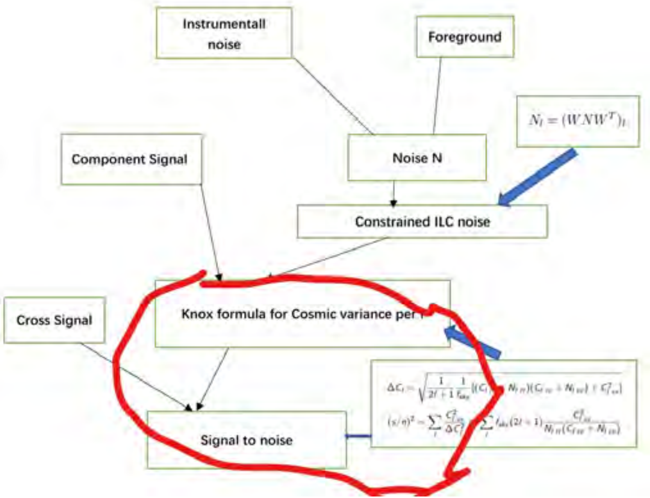
This gives unit response for signal $\vec{a}$ and no response for signal $\vec{b}$.
By doing this, we have no bias.
The resulting weight would be

$$W_{a\ constraint\ b} = \frac{b^T N^{-1} b a^T N^{-1} - a^T N^{-1} b b^T N^{-1}}{a^T N^{-1} a b^T N^{-1} b - (a^T N^{-1} b)^2}$$

Similarly, we have another $W_{b\ constraint\ a}$, which satisfies $W\vec{a} = 0; W\vec{b} = 1$.
The ILC noises are given as $N_l = (WNW^T)_l$.

Procedure

Calculation procedure



Signal to Noise and Cosmic Variance

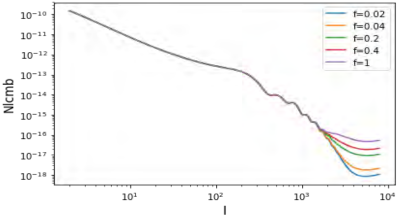
For first detection

$$\Delta C_l = \sqrt{\frac{1}{2l+1}\frac{1}{f_{sky}}[(C_{l\ rr} + N_{l\ rr})(C_{l\ cc} + N_{l\ cc}) + C^2_{l\ xx}]}$$

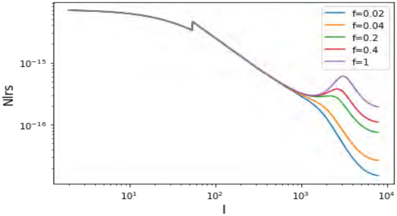
$$(s/n)^2 = \sum_l \frac{C^2_{l\ xx}}{\Delta C^2_l} \approx \sum_l f_{sky}(2l+1)\frac{C^2_{l\ xx}}{N_{l\ rr}(C_{l\ cc} + N_{l\ cc})}$$

ILC Noises

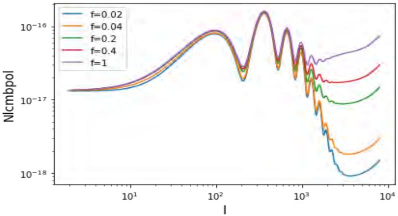
ILC Noise of CMB



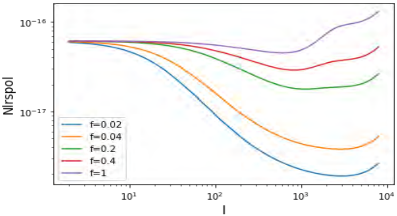
ILC Noise of RS



ILC Noise of CMBpol

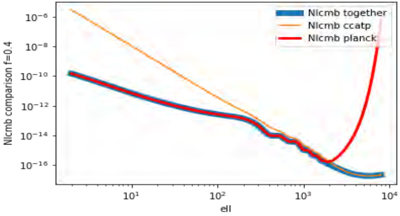


ILC Noise of RSpol

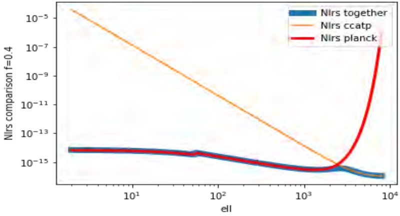


ILC Noises Comparison with separate observations

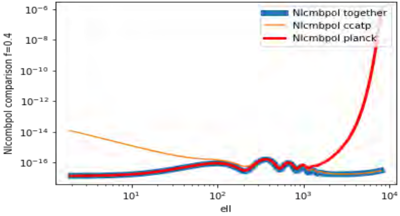
CMB Noises at f=0.4



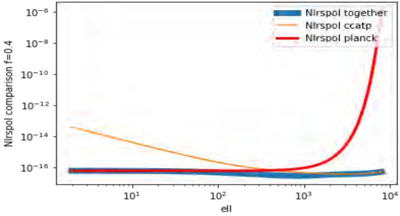
RS Noises at f=0.4



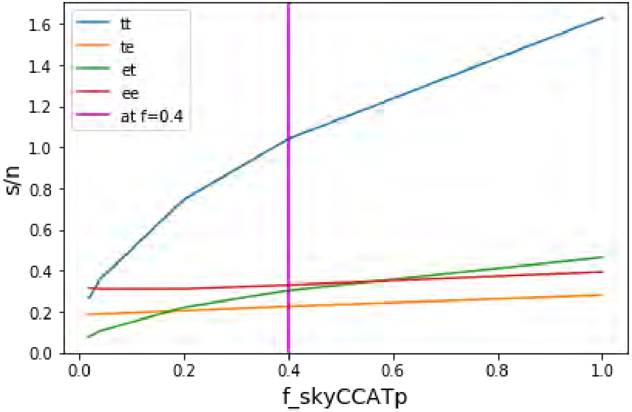
CMBpol Noises at f=0.4



RSpol Noises at f=0.4



Signal to Noise



Significance of foreground to our observation

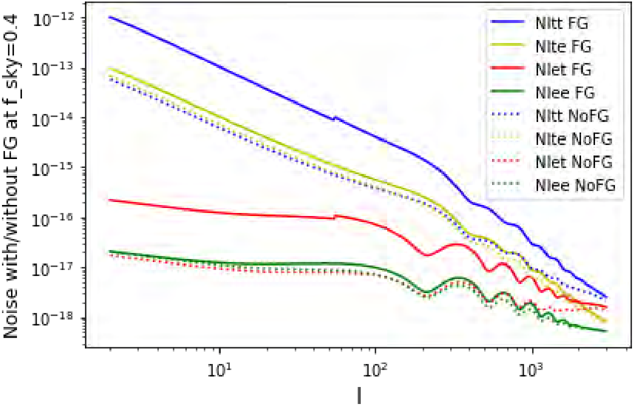
To demonstrate how foreground affects our observation, we run a comparison test without any foregrounds in our covariance matrix. The results are as following:

$f_{sky} = 0.4$	s/n tt	s/n te	s/n et	s/n ee
with fg	1.04	0.23	0.30	0.33
no fg	4.16	0.31	1.39	0.43

We can see that foregrounds overshadow our signals, especially for temperature signals.

Significance of foreground to our observation

Comparison of ILC noises with/without foregrounds



Conclusion

With current experimental configuration, tt observation is the best, but it still does not achieve any detection, mainly due to the dominance of foreground noise. The atmosphere is also a major difficulty for our observation right now.

Future Work

With *CCATp* and *PLANCK*, with our current estimate, it is going to be difficult to detect Rayleigh Signal. Therefore, we will look into what will happen if we introduce other telescopes, for example, Simons Observatory. And we will compare our results with Benjamin Beringue, Daan Meerburg and Joel Meyers.

Bonus: Foreground