Constraining the Astrophysics of the Early Universe using the SARAS Instrumentation

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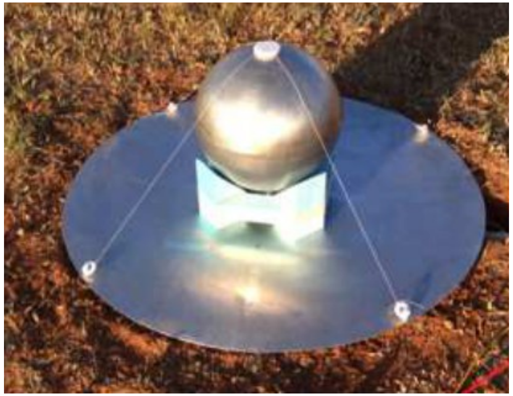
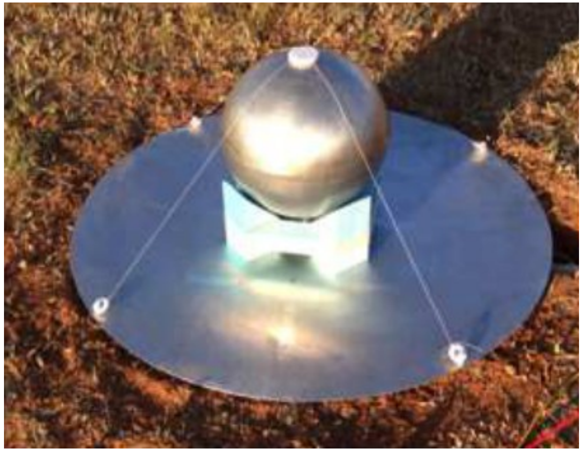
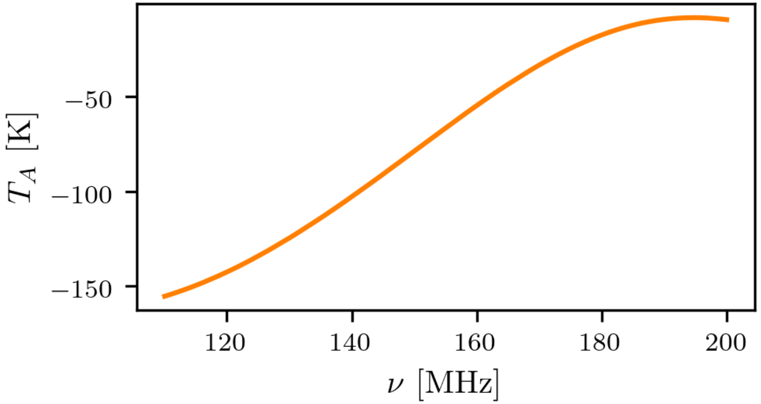
SARAS2 Analysis and Results

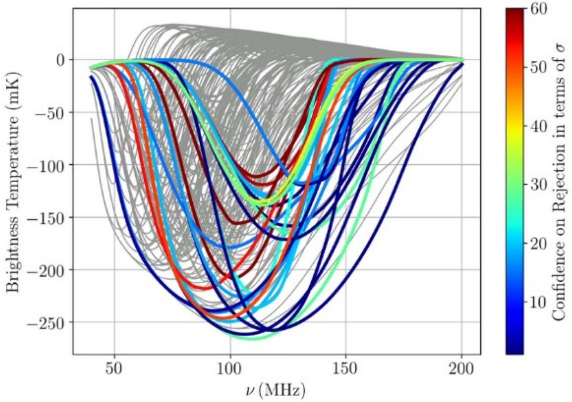
Paper: **https://arxiv.org/abs/2201.11531**



The SARAS2 Data







Singh et al 2017, 2018

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Polynomial Foregrounds →

This Work:

Maximally Smooth Foregrounds (maxsmooth)

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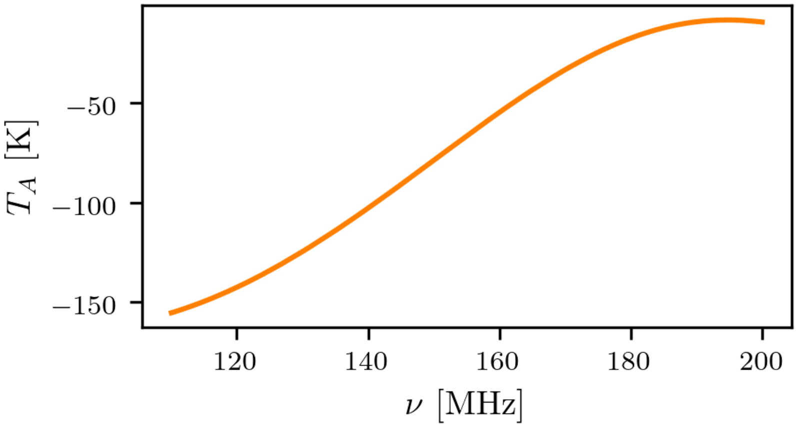
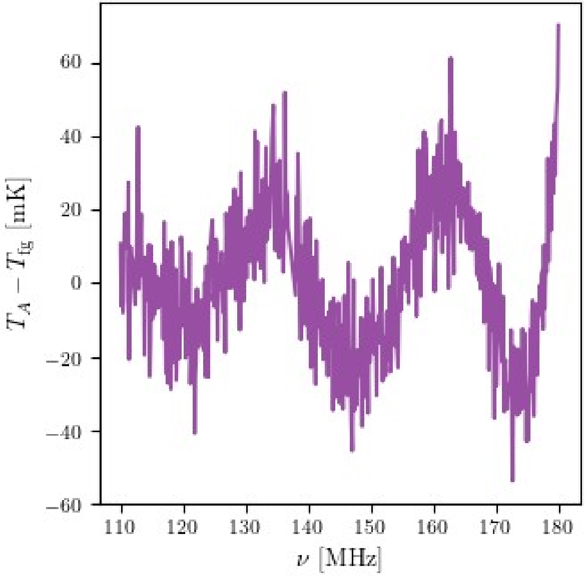
Testing Ground For REACH

Foreground Modelling

$$T^*_{\mathrm{fg}} = T_{\mathrm{fg}}\eta_t \qquad \frac{d^m T^*_{\mathrm{fg}}}{d\nu^m} \leqslant 0 \text{ or } \frac{d^m T^*_{\mathrm{fg}}}{d\nu^m} \geqslant 0 \qquad T^*_{\mathrm{fg}} = \sum_{k=0}^{N-1} a_k(\nu - \nu_0)^k$$





Systematic Modelling

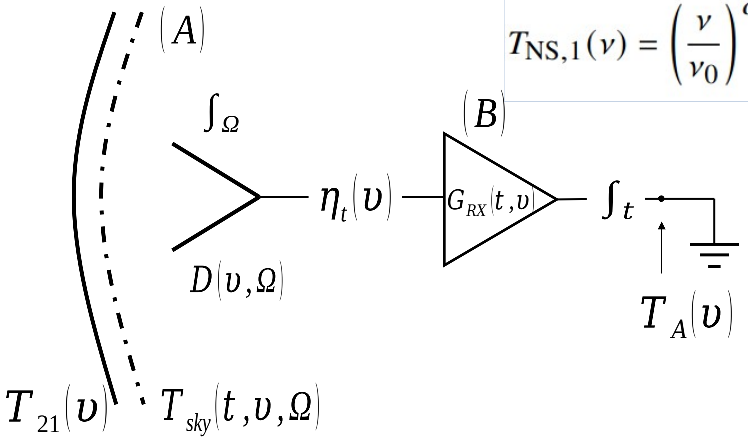
$$T_{\mathrm{A}} = (T_{21} + T_{\mathrm{fg}})\eta_t + T_{\mathrm{NS}}$$

Efficiency:

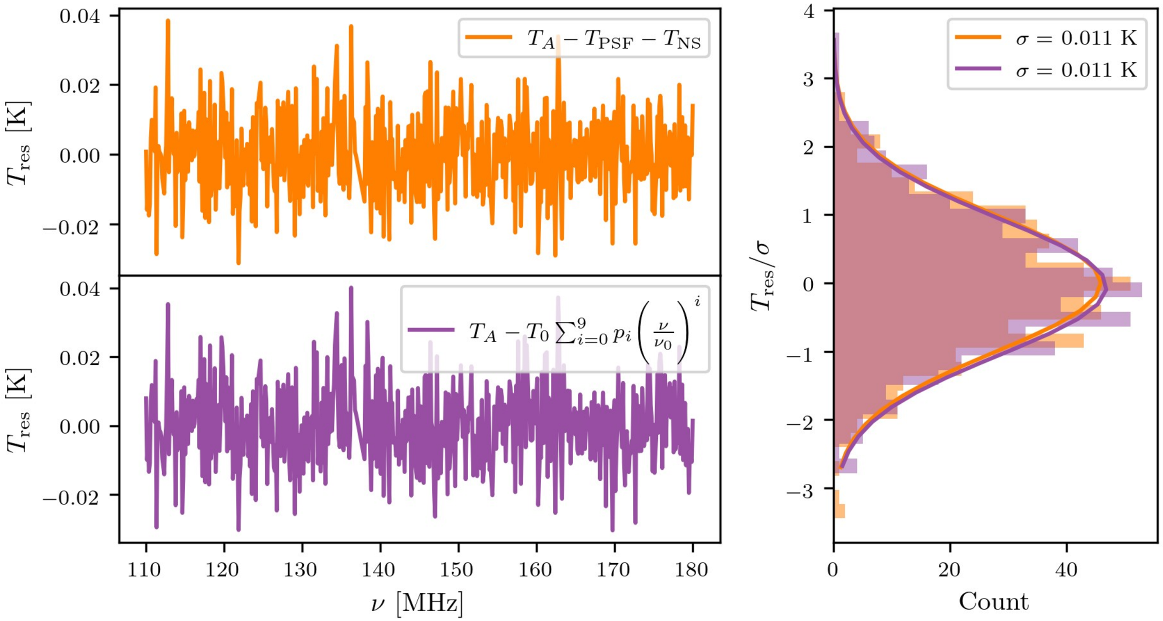
$$T_{\mathrm{NS},2}(\nu) = \eta_t \left(\frac{\nu}{\nu_0}\right)^{\alpha_{\mathrm{sys}}} A \sin\left(\frac{2\pi\nu}{P} + \phi\right)$$

Damped:

$$T_{\mathrm{NS},1}(\nu) = \left(\frac{\nu}{\nu_0}\right)^{\alpha_{\mathrm{sys}}} A \sin\left(\frac{2\pi\nu}{P} + \phi\right)$$



Noise Modelling

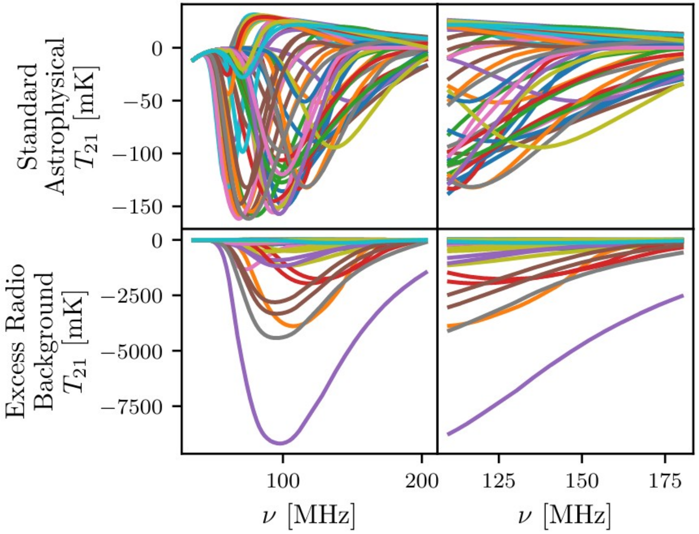


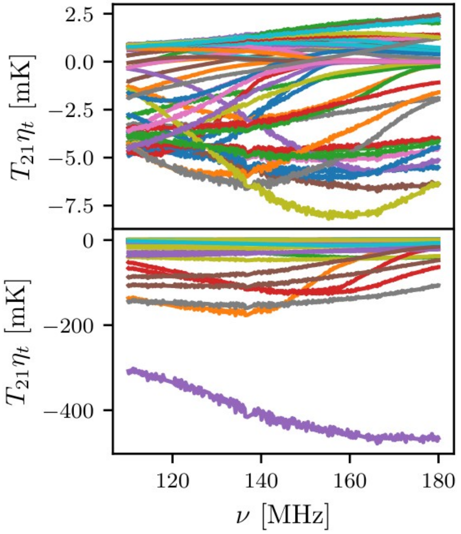
$$\log \mathcal{L} = \sum_i \left(-\frac{1}{2}\log(2\pi\sigma^2) - \frac{1}{2}\left(\frac{T_{\rm A}(\nu_i) - T_{\rm M}(\nu_i)}{\sigma}\right)^2 \right)$$

Noise Model	σ	Prior	Prior Type
Constant	A_σ	$A_\sigma = 10^{-3}$–10^{-1} mK	Log Uniform
Frequency Damped	$A_\sigma \left(\frac{\nu}{\nu_0}\right)^{-\beta_\sigma}$	$A_\sigma = 10^{-4}$–10^{-1} mK	Log Uniform
		$\beta_\sigma = 0 - 5$	Uniform
Relative Weights	$A_\sigma\ W(\nu)$	$A_\sigma = 10^{-2}$–10^{-1} mK	Log Uniform

Table 2. The tested frequency dependent and independent standard deviation models for the assumed Gaussian noise in the SARAS2 data. In the frequency damped noise model ν_0 is the central frequency in the band. The origin of the relative weights, $W(\nu)$, is discussed in section 3.1.

Signal Modelling

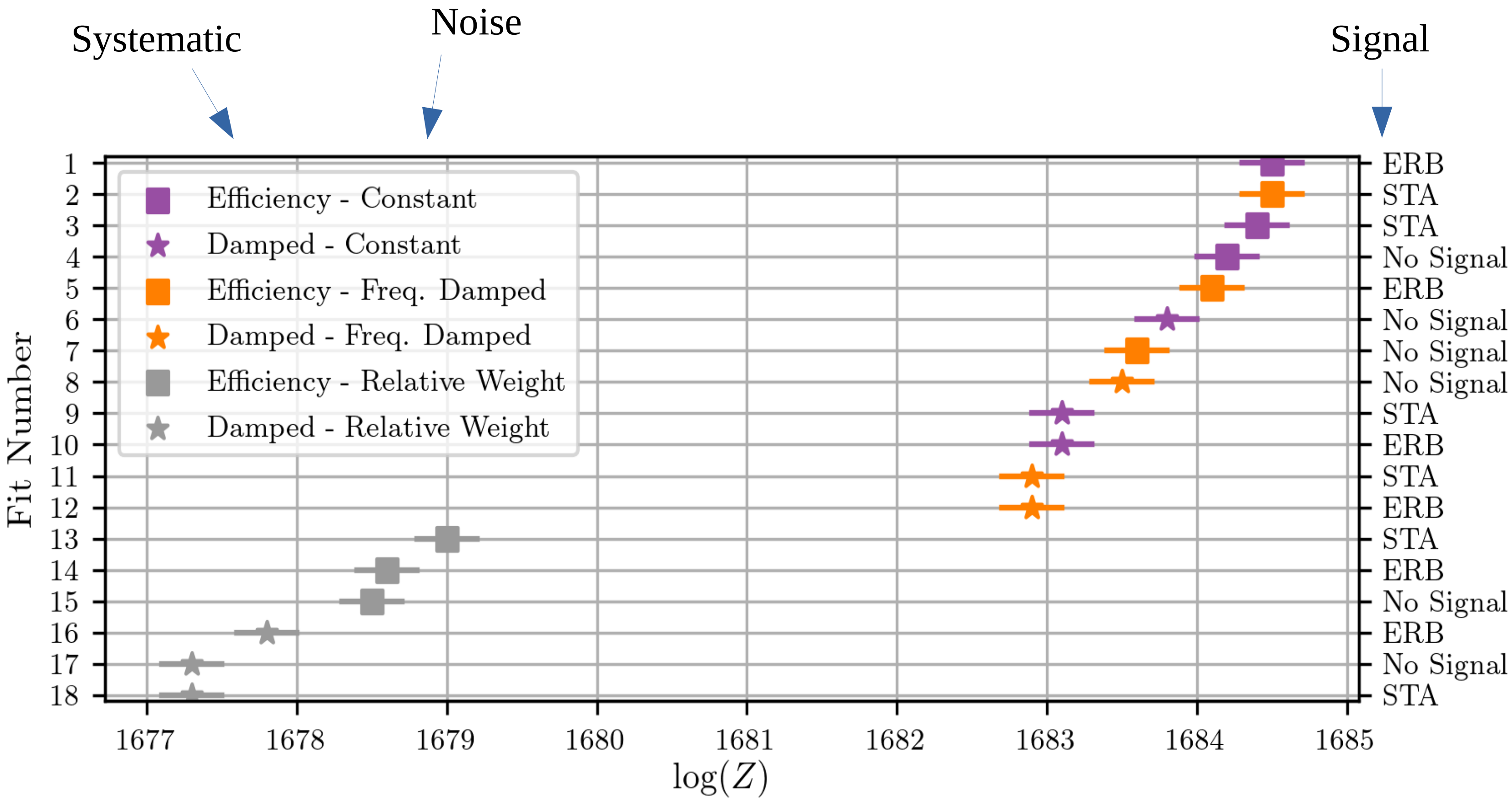




	Parameter	Prior	Prior Type
Signal	τ	0.026 - 0.1 (STA) / 0.035 - 0.077 (ERB)	Uniform
	α	1.3 (STA only)	
	E_{min}	0.1 - 3 keV (STA only)	
	R_{mfp}	30 (STA) / 40 (ERB) Mpc	
	f_*	0.001 - 0.5	Log-Uniform
	V_c	4.2 - 100 km/s	
	f_X	0.0001 - 1000	
	f_{radio}	1 - 99500 (ERB only)	

Models from Reis et al. 2020 and 2021

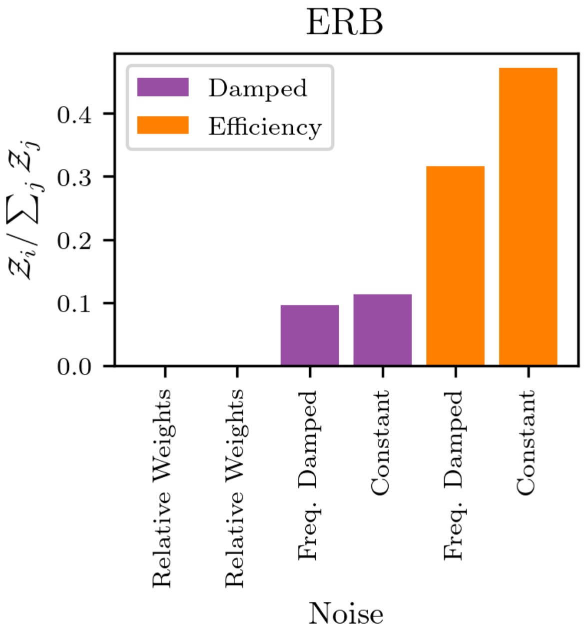
Results



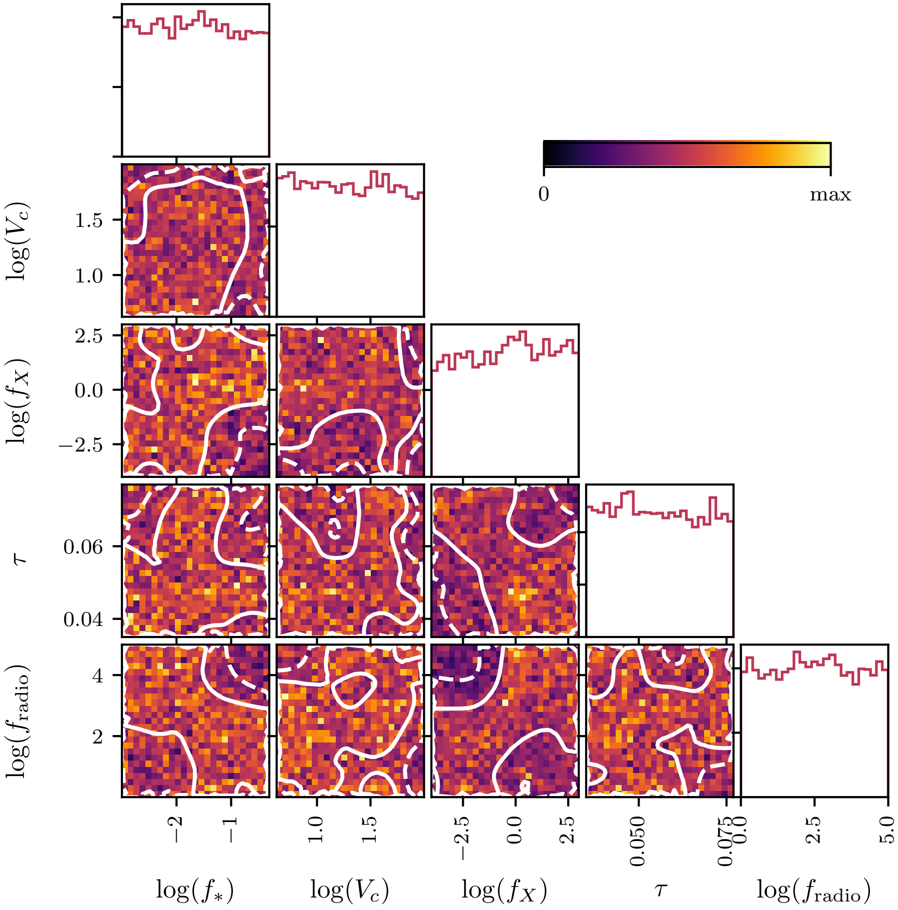
Systematic
Noise
Signal
Efficiency - Constant
Damped - Constant
Efficiency - Freq. Damped
Damped - Freq. Damped
Efficiency - Relative Weight
Damped - Relative Weight
Fit Number
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
ERB
STA
STA
No Signal
ERB
No Signal
No Signal
No Signal
STA
ERB
STA
ERB
STA
ERB
No Signal
ERB
No Signal
STA
1677
1678
1679
1680
1681
1682
1683
1684
1685
log(Z)

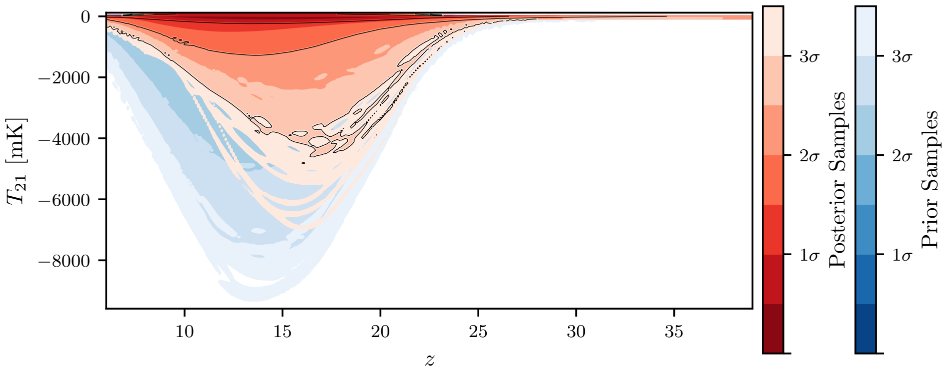
Results

$$P_{\text{combined}}(\theta|D,M) = \sum_i w_i P_i(\theta|D,M) \qquad w_i = Z_i/\sum_j Z_j$$



Results – Radio Galaxy Excess Background

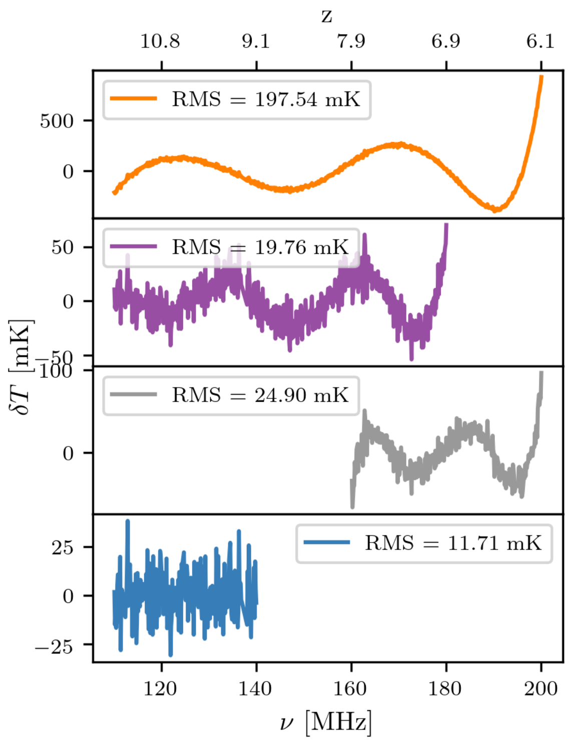




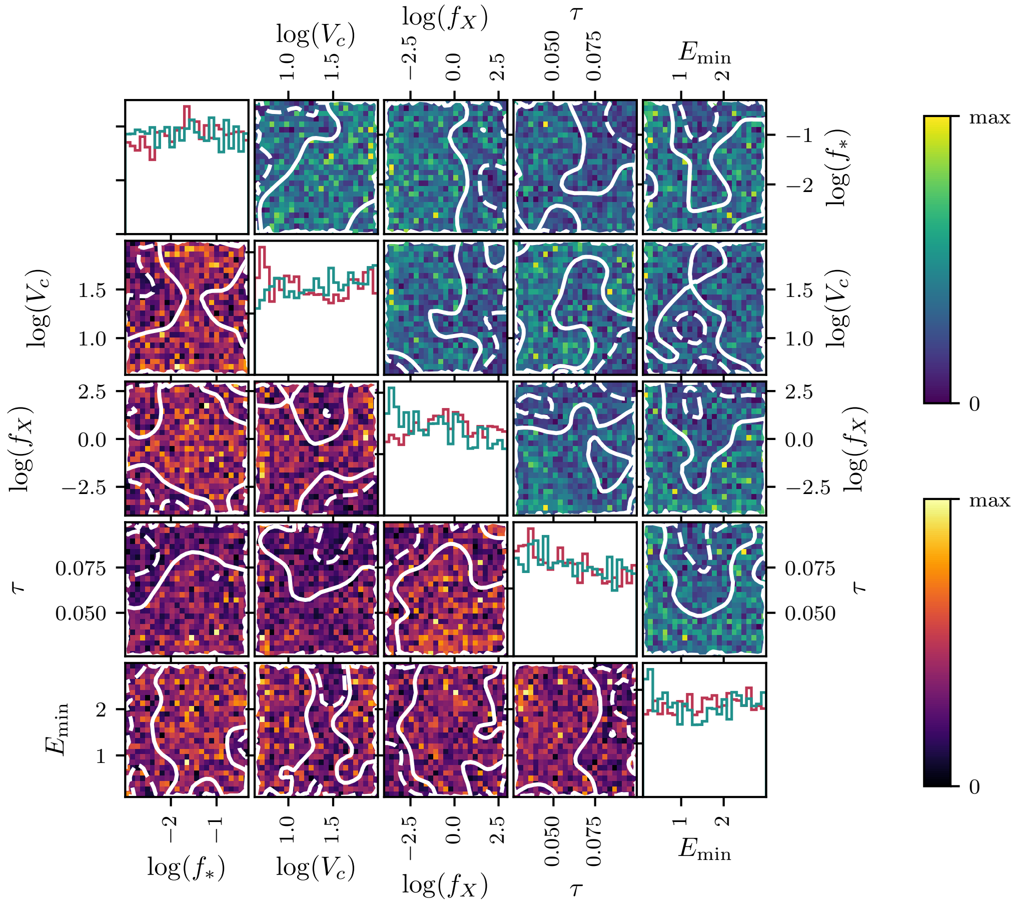
Conclusions

- SARAS2 has provided constraints on the magnitude of any excess radio background from high redshift radio galaxies above the CMB.
- We have identified a systematic in the SARAS2 data (probably ground emission).
- The workflow used here could be applied to REACH data...

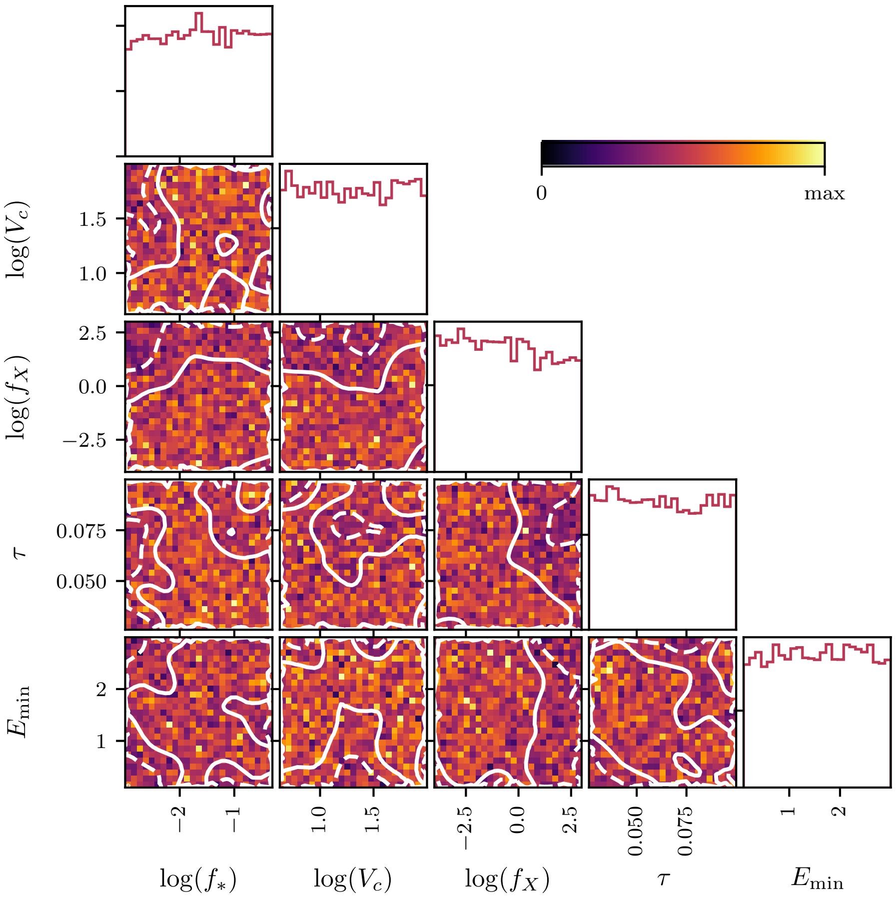
SARAS2 Foreground Modelling

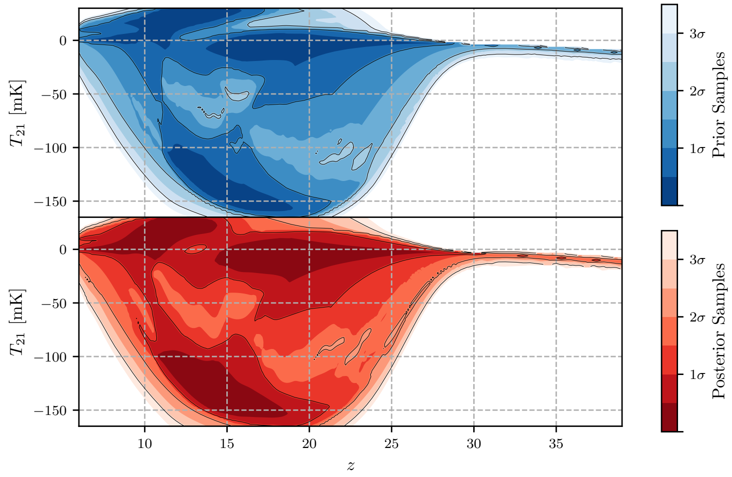


Reproducibility

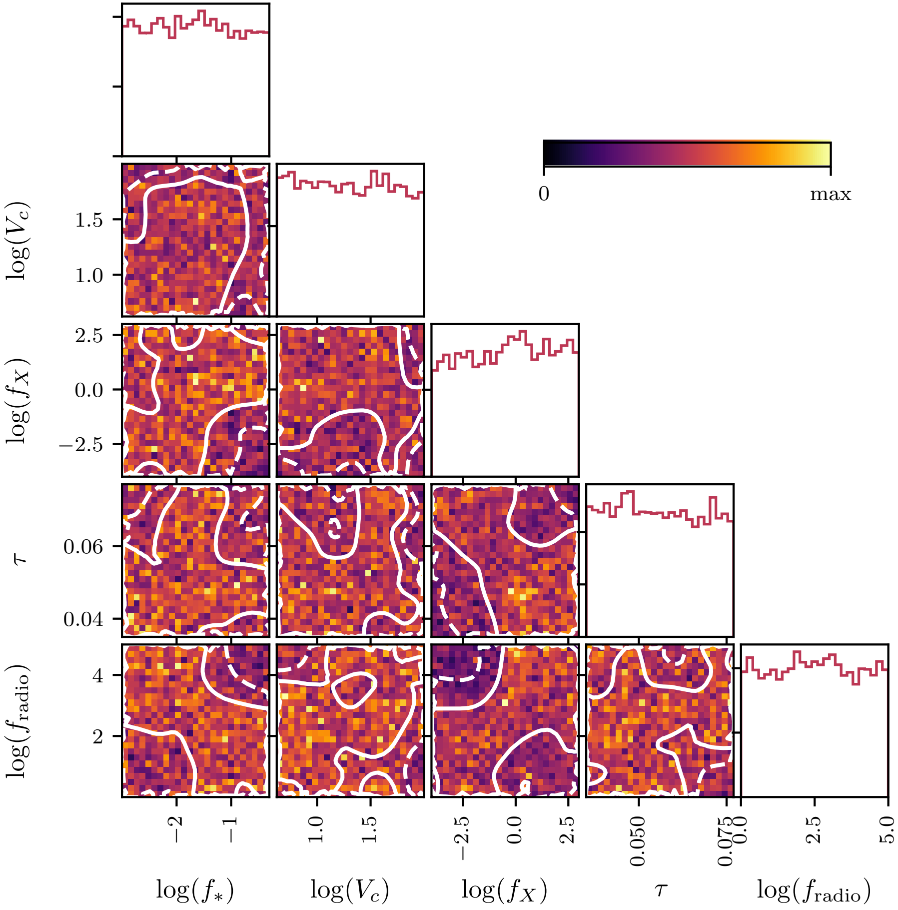


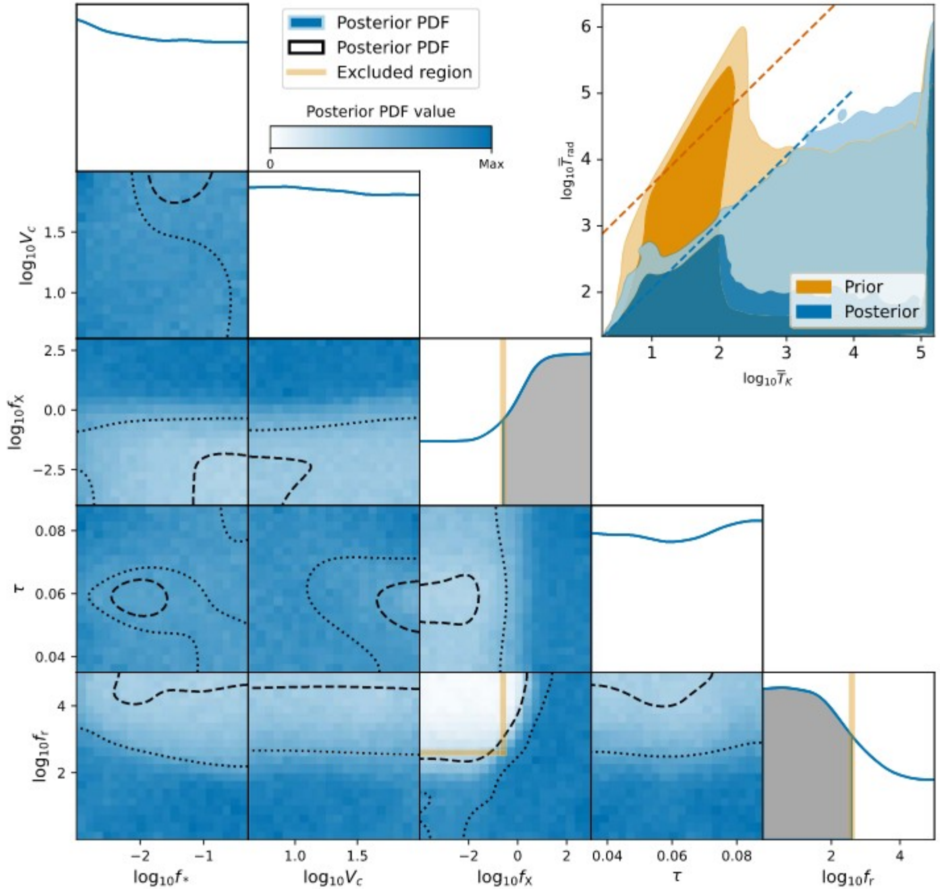
“Standard” Signals





Results – In the Context of HERA





*The HERA Collaboration 2022