

Constraining the Astrophysics of the Early Universe using the SARAS Instrumentation

Harry T. J. Bevins

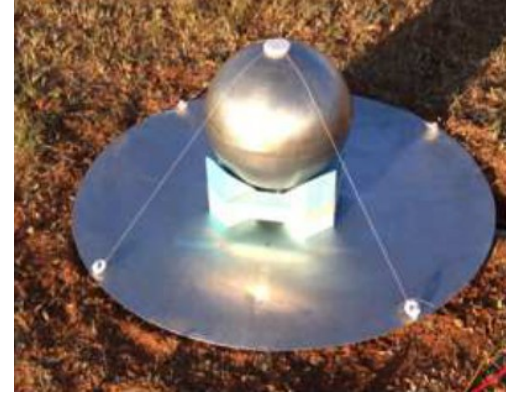
Cavendish Astrophysics, University of Cambridge

In collaboration with;

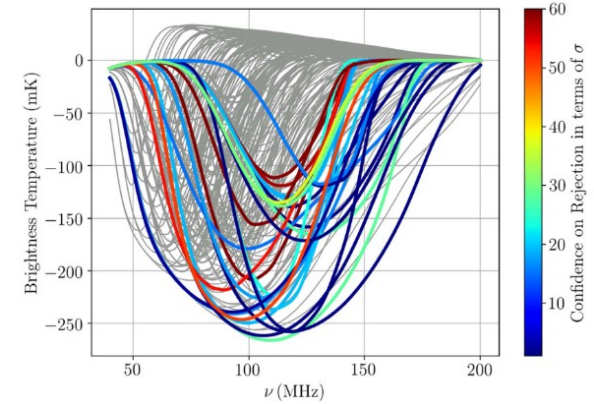
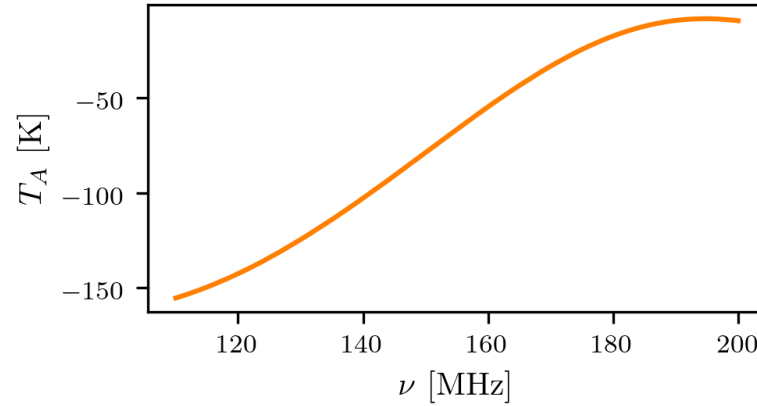
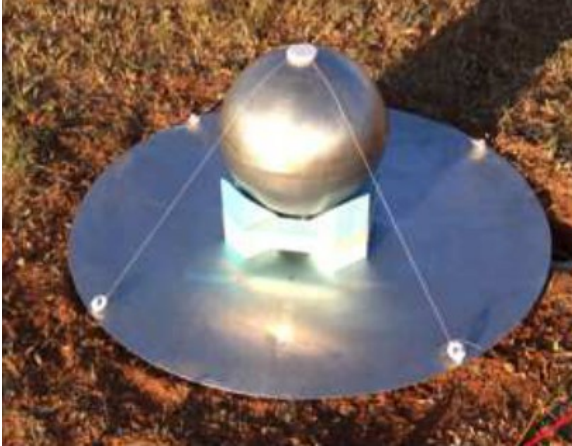
Eloy de Lera Acedo, Anastasia Fialkov, Will Handley, Saurabh Singh,
Ravi Subrahmanyan and Rennan Barkana

SARAS2 Analysis and Results

Paper: <https://arxiv.org/abs/2201.11531>



The SARAS2 Data



Singh et al 2017, 2018

What are we doing differently?



Previously:

Polynomial Foregrounds



This Work:

Maximally Smooth Foregrounds
(maxsmooth)

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Modelling



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Separate Systematic/Foreground
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Gaussian Noise w/ Different σ
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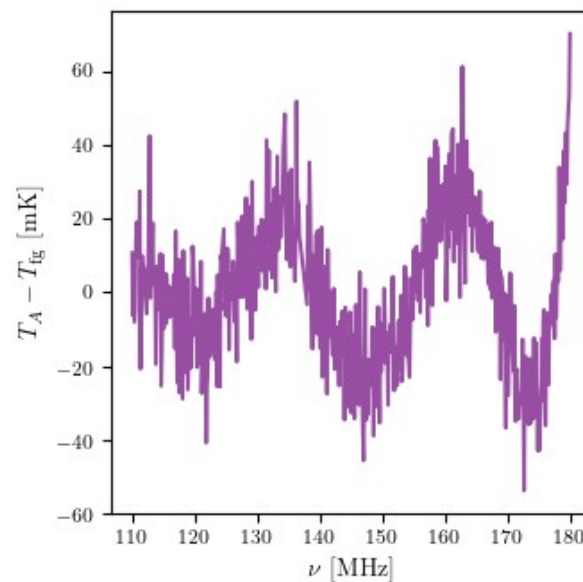
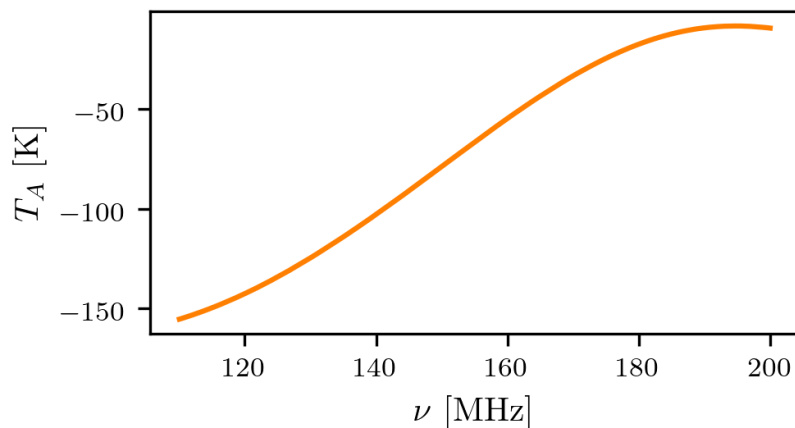
Testing Ground For
REACH

Foreground Modelling



$$T_{\text{fg}}^* = T_{\text{fg}} \eta_t \quad \frac{d^m T_{\text{fg}}^*}{d\nu^m} \leq 0 \quad \text{or} \quad \frac{d^m T_{\text{fg}}^*}{d\nu^m} \geq 0$$

$$T_{\text{fg}}^* = \sum_{k=0}^{N-1} a_k (\nu - \nu_0)^k$$



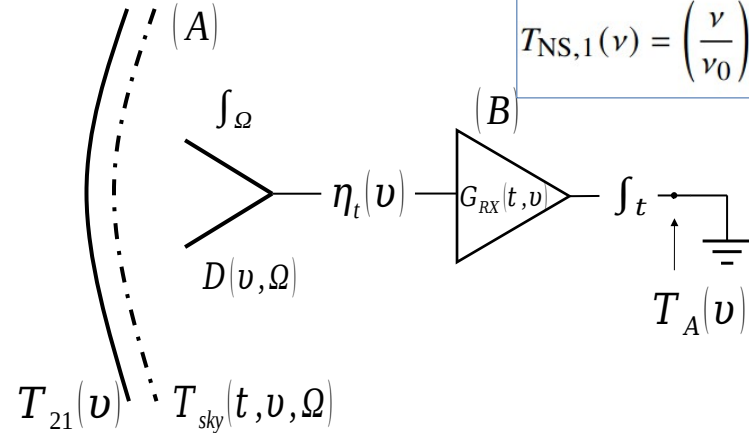
$$T_A = (T_{21} + T_{fg})\eta_t + T_{NS}$$

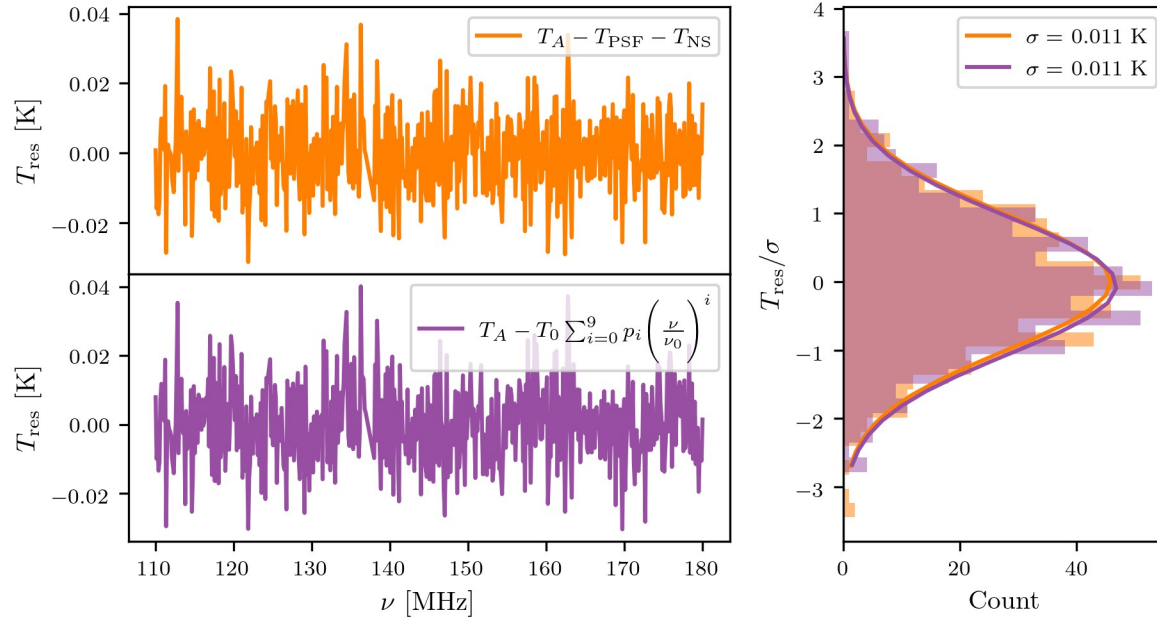
Efficiency:

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

Damped:

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

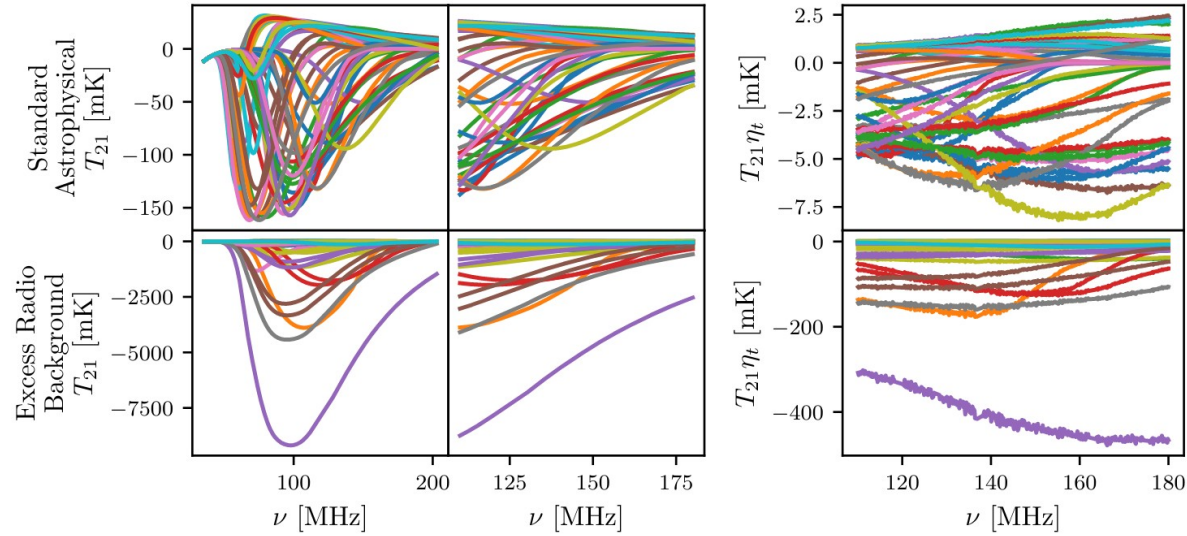




$$\log \mathcal{L} = \sum_i \left(-\frac{1}{2} \log(2\pi\sigma^2) - \frac{1}{2} \left(\frac{T_A(\nu_i) - T_M(\nu_i)}{\sigma} \right)^2 \right)$$

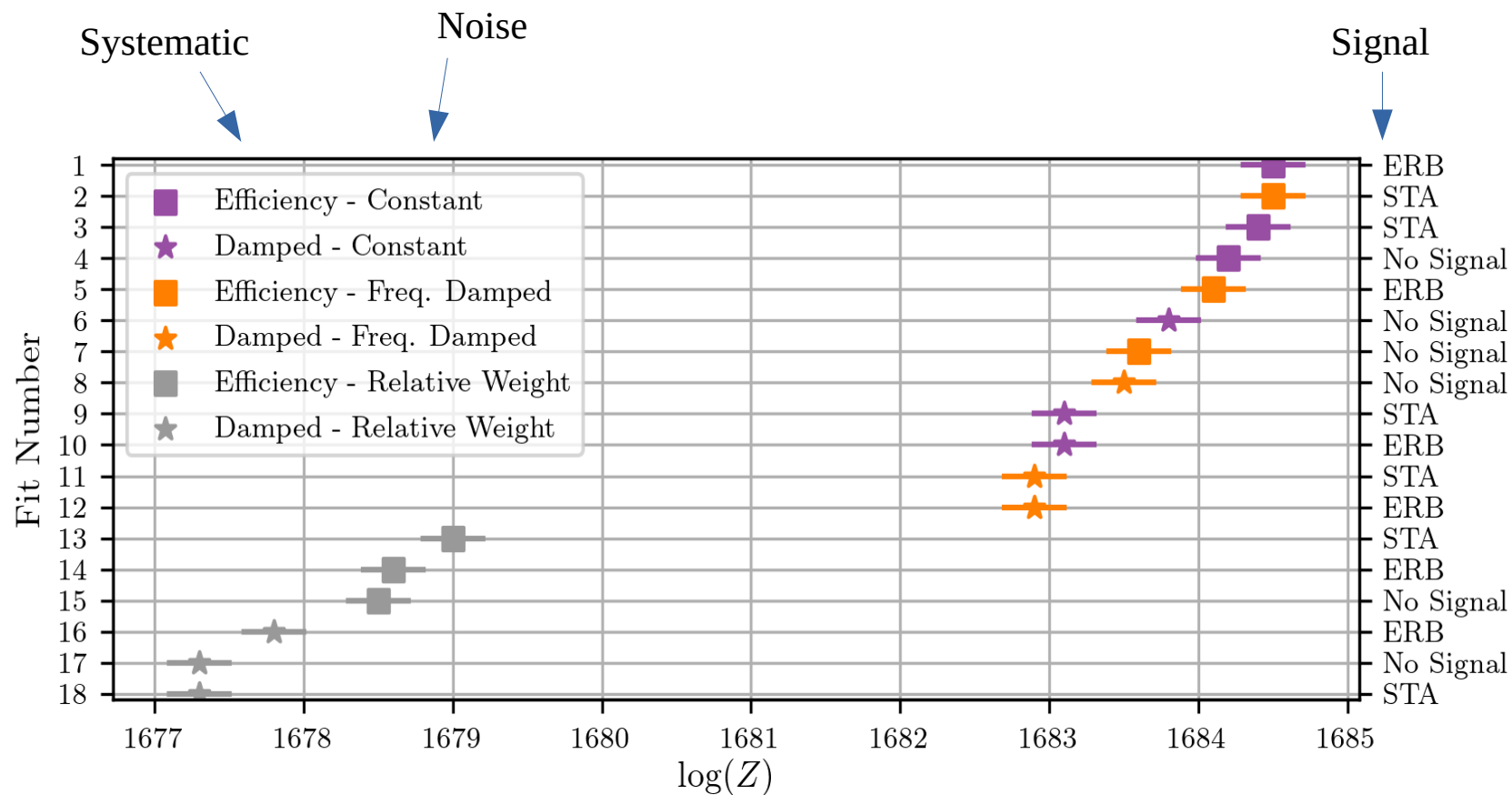
Noise Model	σ	Prior	Prior Type
Constant	A_σ	$A_\sigma = 10^{-3} - 10^{-1}$ mK	Log Uniform
Frequency Damped	$A_\sigma \left(\frac{\nu}{\nu_0} \right)^{-\beta_\sigma}$	$A_\sigma = 10^{-4} - 10^{-1}$ mK	Log Uniform
		$\beta_\sigma = 0 - 5$	Uniform
Relative Weights	$A_\sigma W(\nu)$	$A_\sigma = 10^{-2} -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

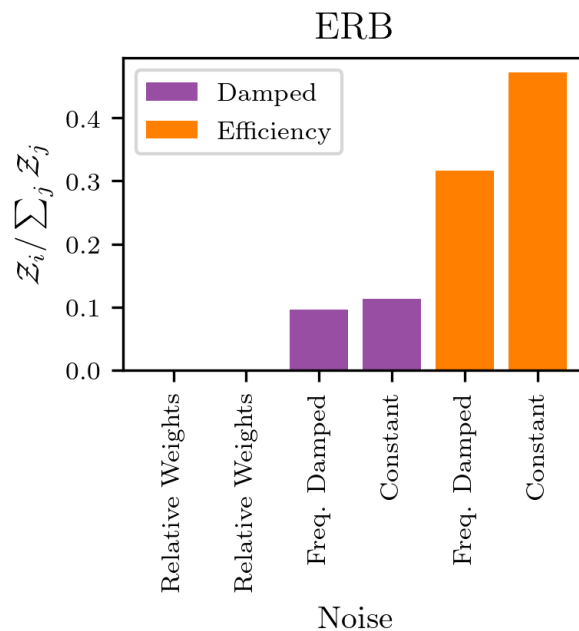


	Parameter	Prior	Prior Type
Signal	τ	0.026 - 0.1 (STA) / 0.035 - 0.077 (ERB)	Uniform
	α	1.3 (STA only)	
	E_{\min}	0.1 - 3 keV (STA only)	
	R_{mlf}	30 (STA) / 40 (ERB) Mpc	Log-Uniform
	f_*	0.001 - 0.5	
	V_c	4.2 - 100 km/s	
	f_X	0.0001 - 1000	
	f_{radio}	1 - 99500 (ERB only)	

Models from Reis et al. 2020 and 2021



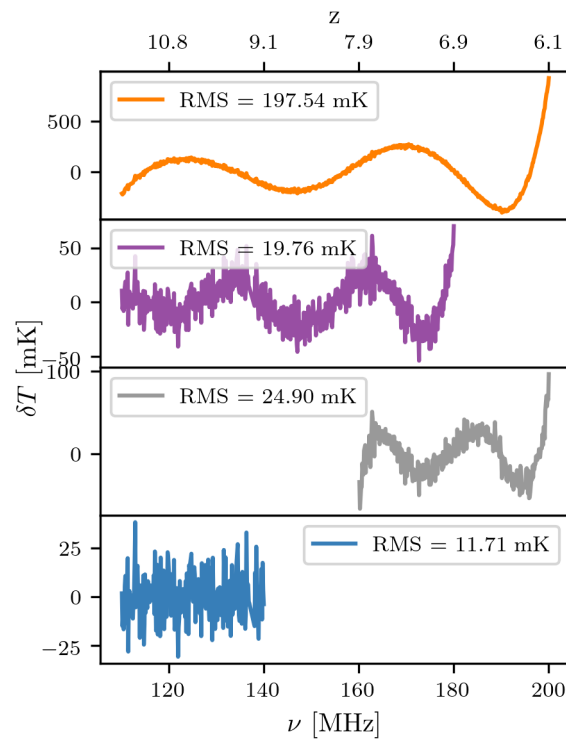
$$P_{\text{combined}}(\theta|D, M) = \sum_i w_i P_i(\theta|D, M) \quad w_i = Z_i / \sum_j Z_j$$



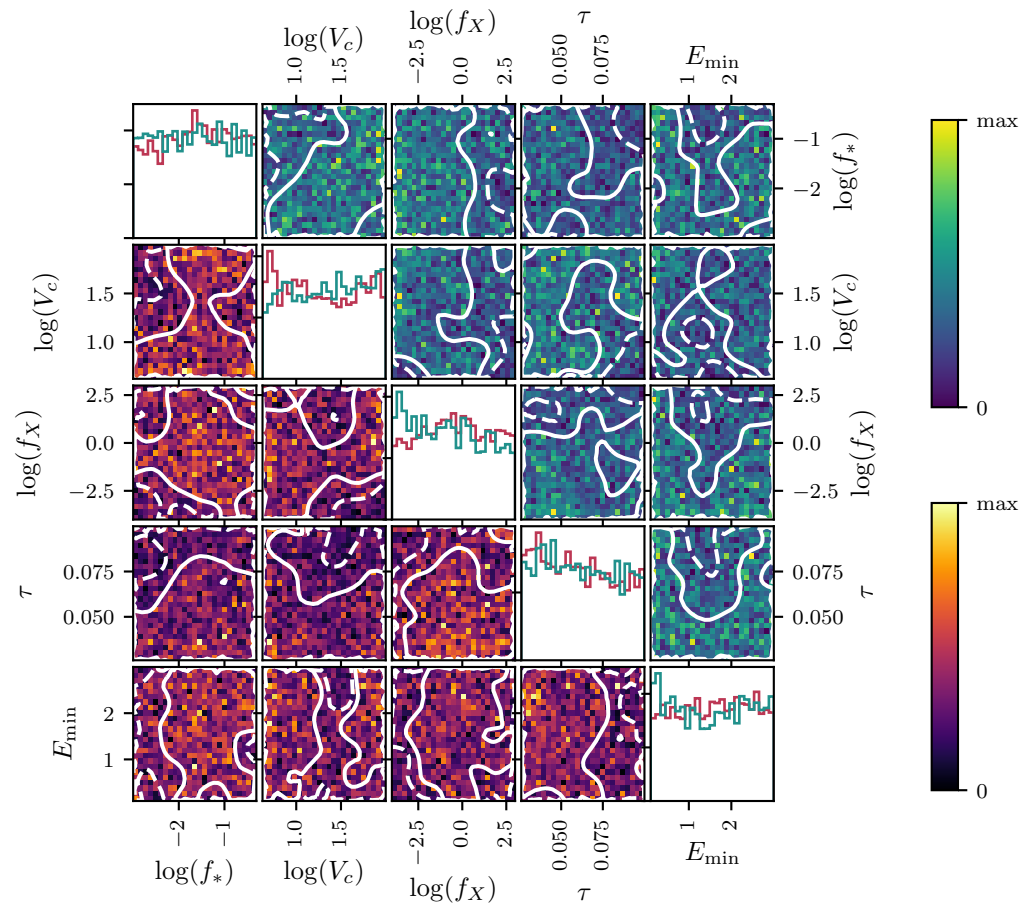
Results – Radio Galaxy Excess Background

- 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...

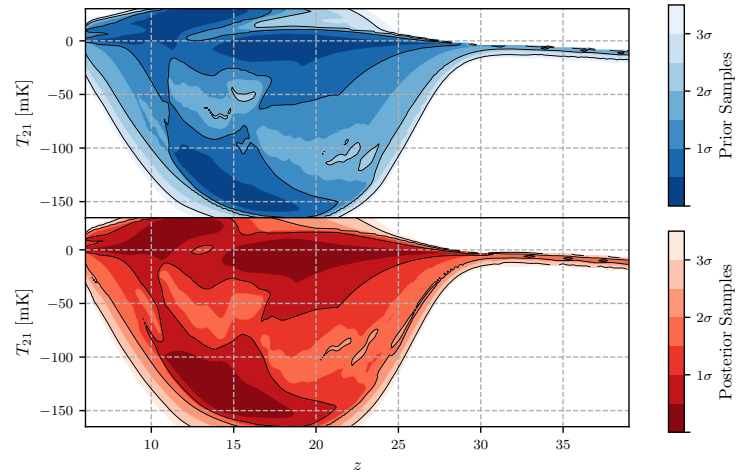
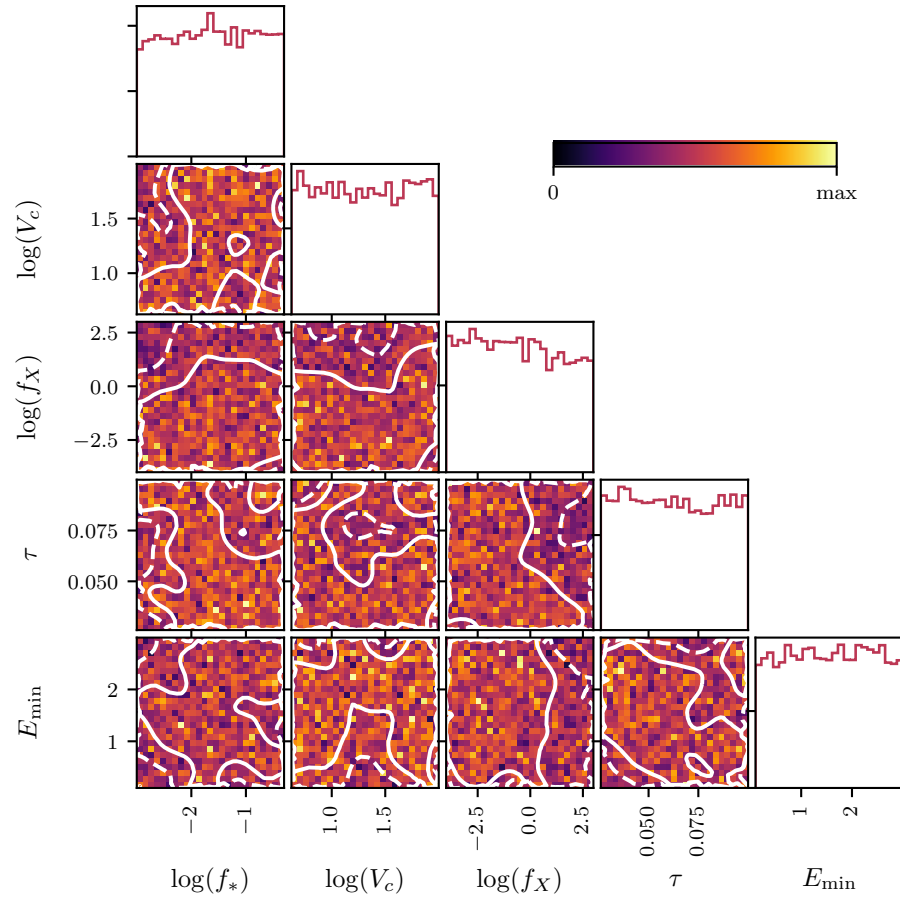
SARAS2 Foreground Modelling



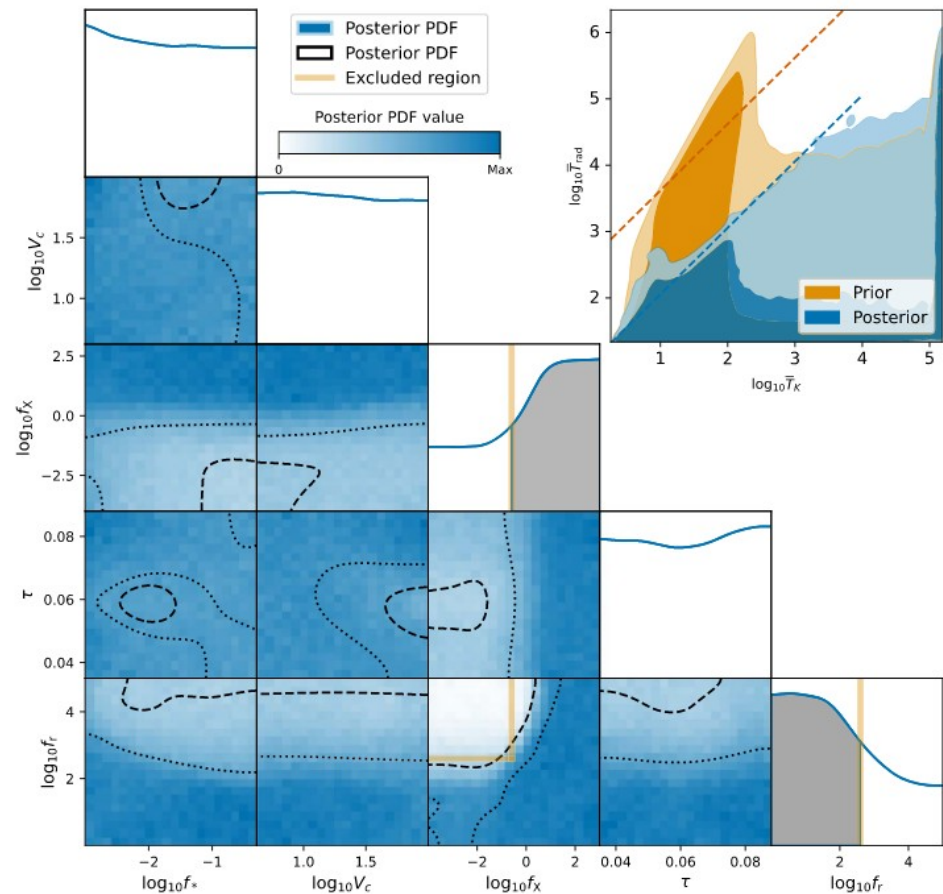
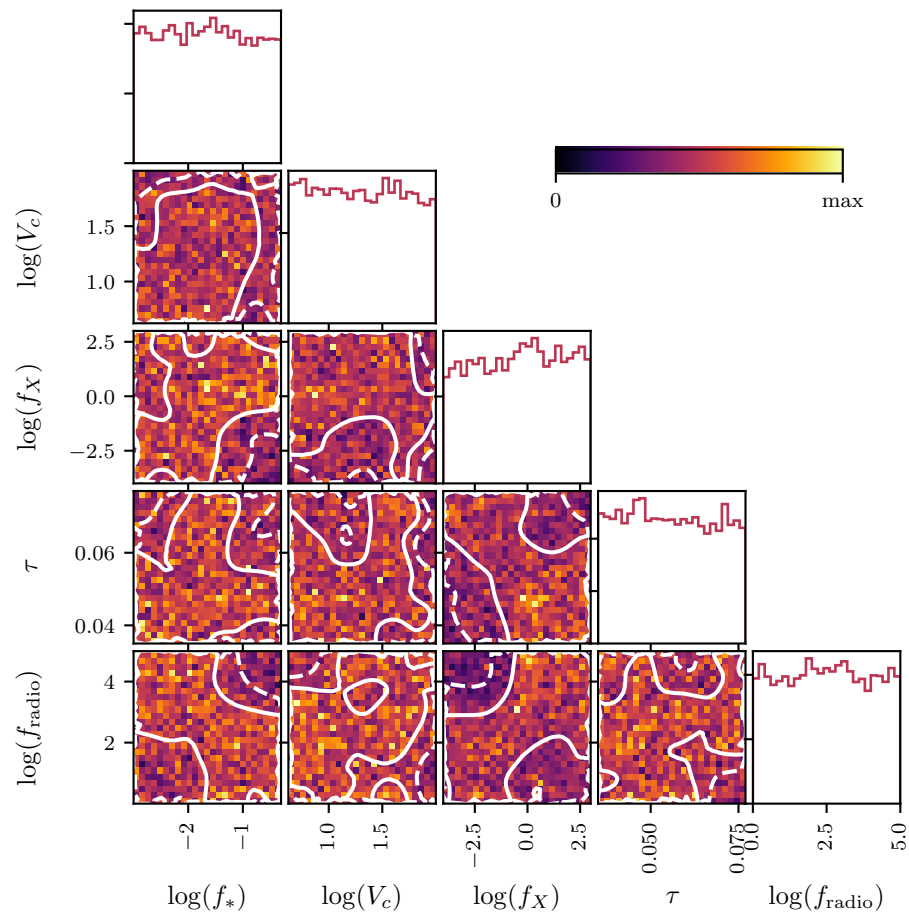
Reproducibility



“Standard” Signals



Results – In the Context of HERA



*The HERA Collaboration 2022