DETECTING THE EXTRAGALACTIC RADIO BACKGROUND USING GLOBAL 21 CM SIGNAL EXPERIMENTS

Cosmology in the Alps Conference

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THE EXTRAGALACTIC RADIO BACKGROUND

- The extragalactic radio background (ERB) remains poorly constrained at low frequencies
- A possible excess above known source populations has been detected (e.g. Fixsen et al. (2011), Dowell & Taylor (2018))
- A genuine radio excess would have important implications for:
  - Early galaxy populations
  - Cosmic-ray physics
  - Global 21 cm cosmology
- **Key Question:** Can a global 21 cm experiment independently detect — or even constrain — the ERB amplitude?

GLOBAL SIGNAL OBSERVATIONS

Global 21 cm experiments see a sky averaged temperautre:

$$T(t_0,\nu) = \frac{\int_\Omega T_{\rm sky}(t_0,\nu,\ell,b)\,A(\nu,\ell,b)\,d\ell\,db}{\int_\Omega A(\nu,\ell,b)\,d\ell\,db} + T_N(t_0,\nu) \qquad (1)$$

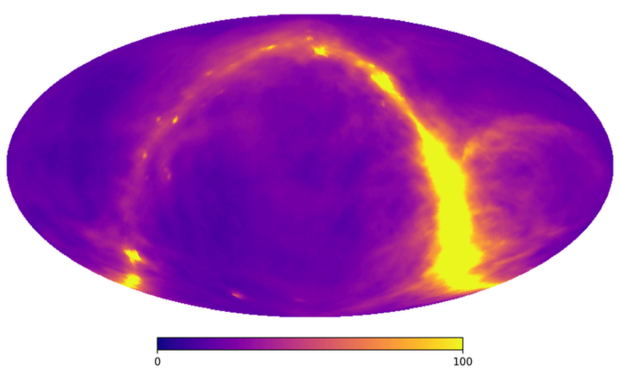

Fig. 1: Galactic Synchrotron Foreground at 408 MHz (Remazeilles et al. 2014)

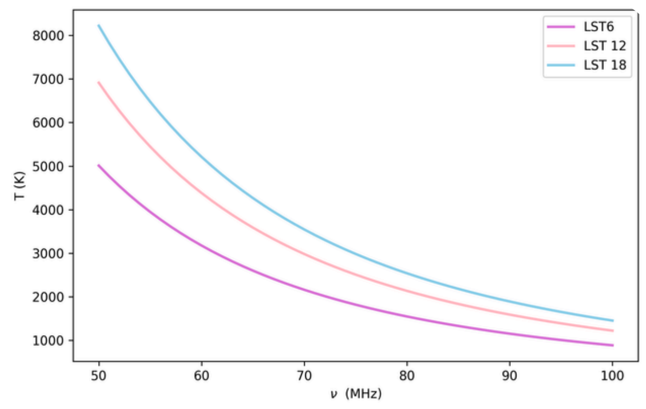

Fig. 2: Simulated Global Signal Spectra at different LSTs

DATA SIMULATION & MODEL

- ERB is simulated with $T_R = 14K(\nu_0 = 408MHz)$ and added to foregrounds
- Foregrounds are simulated by dividing the Haslam map into three regions: high-latitude, galactic plane, and outer plane, as illustrated below:

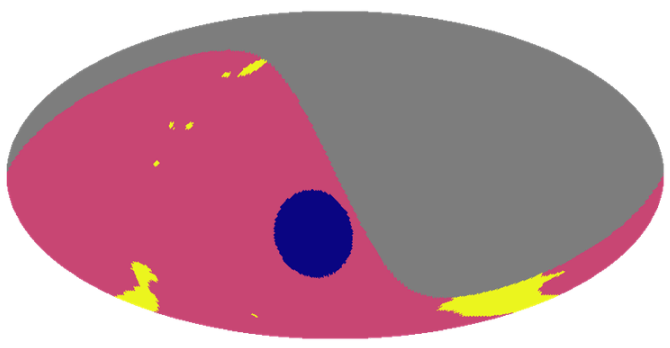

Fig. 3: Visual for 3 regions of foregrounds as seen in **Eqn. 2**

$$T(\nu) = T_R(\nu_0)\left(\frac{\nu}{\nu_0}\right)^{\beta_R} + \frac{\int_{\Omega'}[T_{\rm H}(\nu_0,\ell,b) - T_R(\nu_0)]\left(\frac{\nu}{\nu_0}\right)^{\beta_{\rm HG}} A(\nu,\ell,b)\,d\ell\,db}{\int_\Omega A(\nu,\ell,b)\,d\ell\,db} + \frac{\int_{\Omega_{\rm P}} T_{\rm P}(\nu_0,\ell,b)\left(\frac{\nu}{\nu_0}\right)^{\beta_{\rm P}} A(\nu,\ell,b)\,d\ell\,db}{\int_\Omega A(\nu,\ell,b)\,d\ell\,db} + \frac{\int_{\Omega_{\rm O}} T_{\rm O}(\nu_0,\ell,b)\left(\frac{\nu}{\nu_0}\right)^{\beta_{\rm O}} A(\nu,\ell,b)\,d\ell\,db}{\int_\Omega A(\nu,\ell,b)\,d\ell\,db} + T_N(\nu) \qquad (2)$$

MCMC SETUP

- Simulated data (right) is fit with MCMC
- Likelihood constructed:

$$\ln\mathcal{L}(\theta) = -\frac{1}{2}\sum_i\left[\frac{(y_i - y_{\text{model},i}(\theta))^2}{\sigma^2} + \ln(\sigma^2)\right]$$

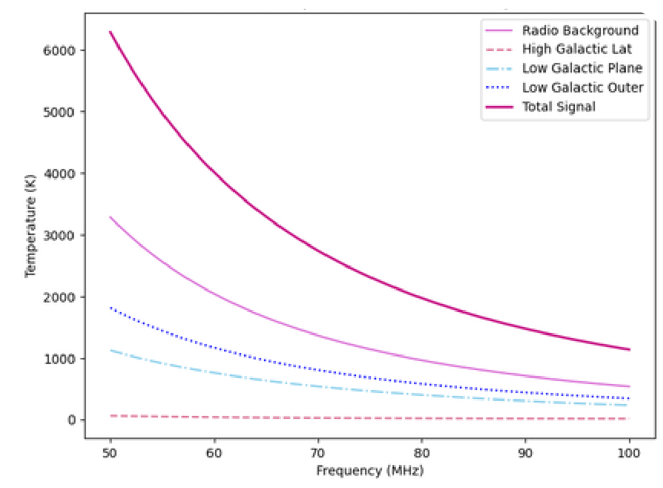

Fig. 4: Simulated Spectrum

5-PARAMETER FIT

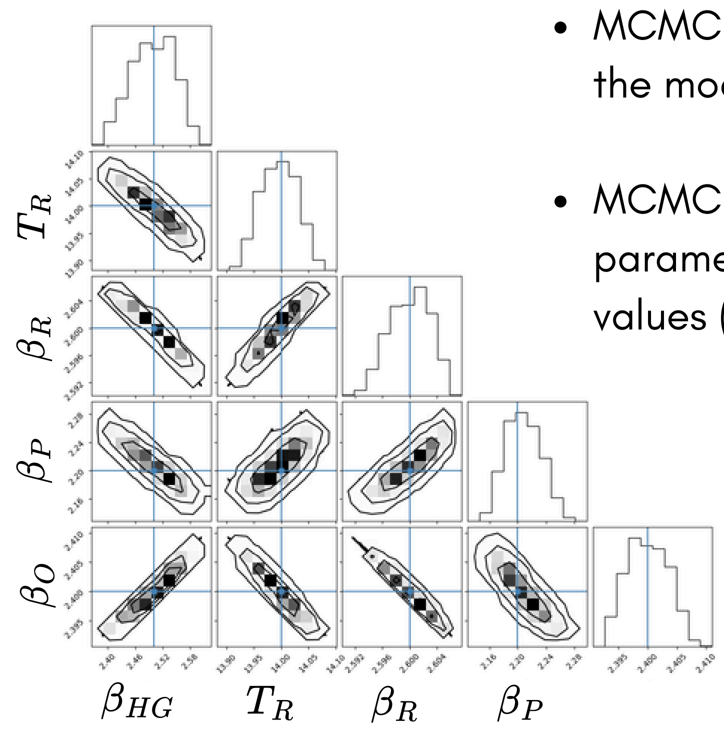

Fig. 5: Posterior distributions for the five fitted parameters

- MCMC fits for 5 parameters as seen in the model
- MCMC successfully recovers all 5 parameters in agreement with the true values (see **Tab. 1**)

Parameter	True Value	Fitted Value
T_R	14	14.00 ± 0.04
β_R	2.6	2.600 ± 0.003
β_{HG}	2.5	2.50 ± 0.05
β_P	2.2	2.21 ± 0.03
β_O	2.4	2.400 ± 0.004

Tab. 1: Best fits for the 5-parameter Fit

6-PARAMETER FIT

- Inclusion of a nuisance parameter to absorb unmodelled systematic errors
- Simulated systematic error is injected into the simulated data
- MCMC successfully recovers the ERB amplitude within 1 sigma

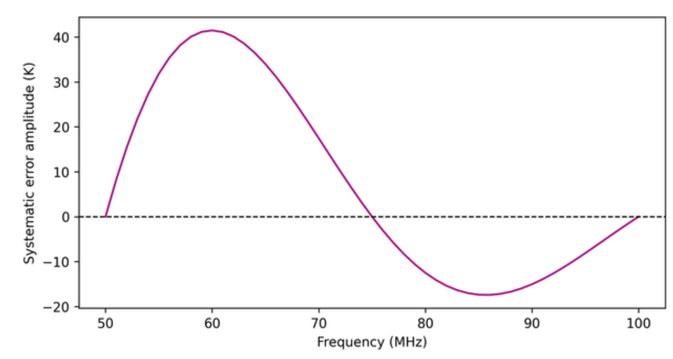

Fig. 6: Simulated Systematic Error, 1% amplitudeof the simulated spectrum

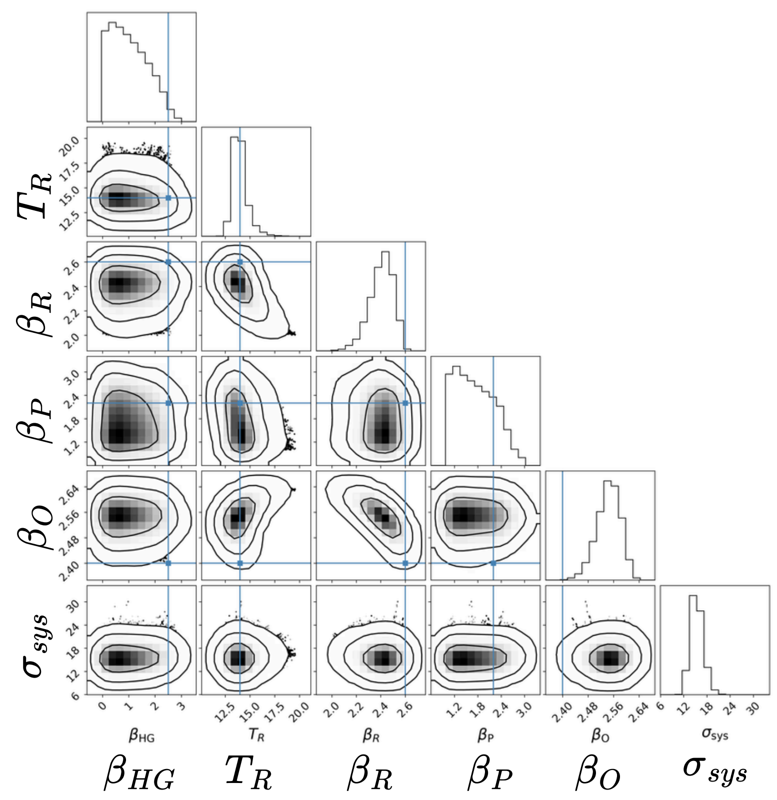

Fig. 7: Posterior distributions for the six fitted parameters

Parameter	True Value	Fitted Value
T_R [K]	14	13.49 ± 0.67
β_{Gal}	2.5	2.28 ± 0.21
β_R	2.6	2.39 ± 0.11
β_P	2.2	2.33 ± 0.25
β_O	2.4	2.55 ± 0.04
σ_{sys}	–	15.97 ± 1.71

Tab. 2: Best fits for the 6-parameter Fit

CONCLUSION

ERB amplitude is recoverable in simulations, both in an ideal case and with 1% unmodelled error, demonstrating the possibility to separate from foregrounds

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