SCUOLA NORMALE SUPERIORE

Pop III radio galaxies and EDGES

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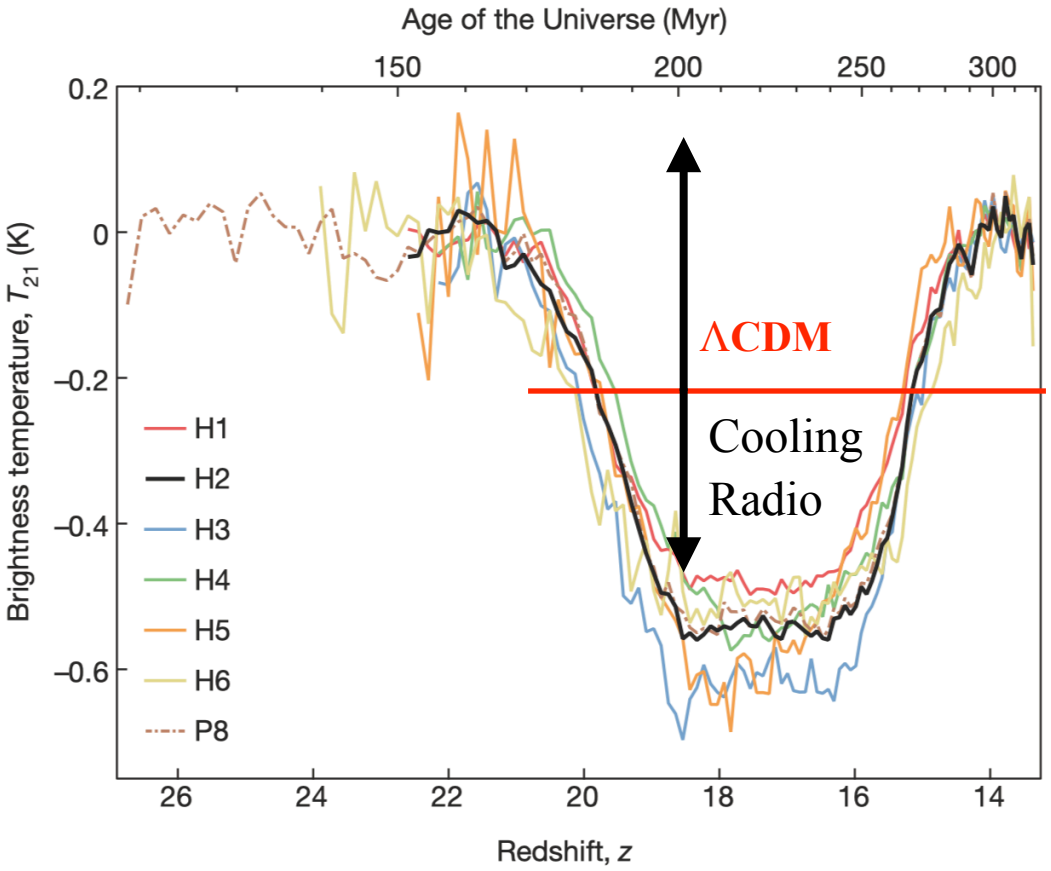
In collab with: Andrei Mesinger, Steven Murray, Daniela Brietman, Yuxiang Qin

ArXiv 2408.xxxx

SKA CD/EoR meeting, Tsinghua 2024

B18 Detection claim



Issues with Bowman18 (B18):

- Wrong shape (Flat Gaussian, flat+steep)
- Too deep

How to get a deep signal?

$$\delta T_b(\nu) \approx 27 x_{\rm HI}(1+\delta_{\rm nl}) \left(\frac{H}{dv_r/dr + H}\right) \left(1 - \frac{T_\gamma}{T_S}\right) \left(\frac{1+z}{10}\frac{0.15}{\Omega_M h^2}\right)^{1/2} \left(\frac{\Omega_b h^2}{0.023}\right) \text{mK}$$

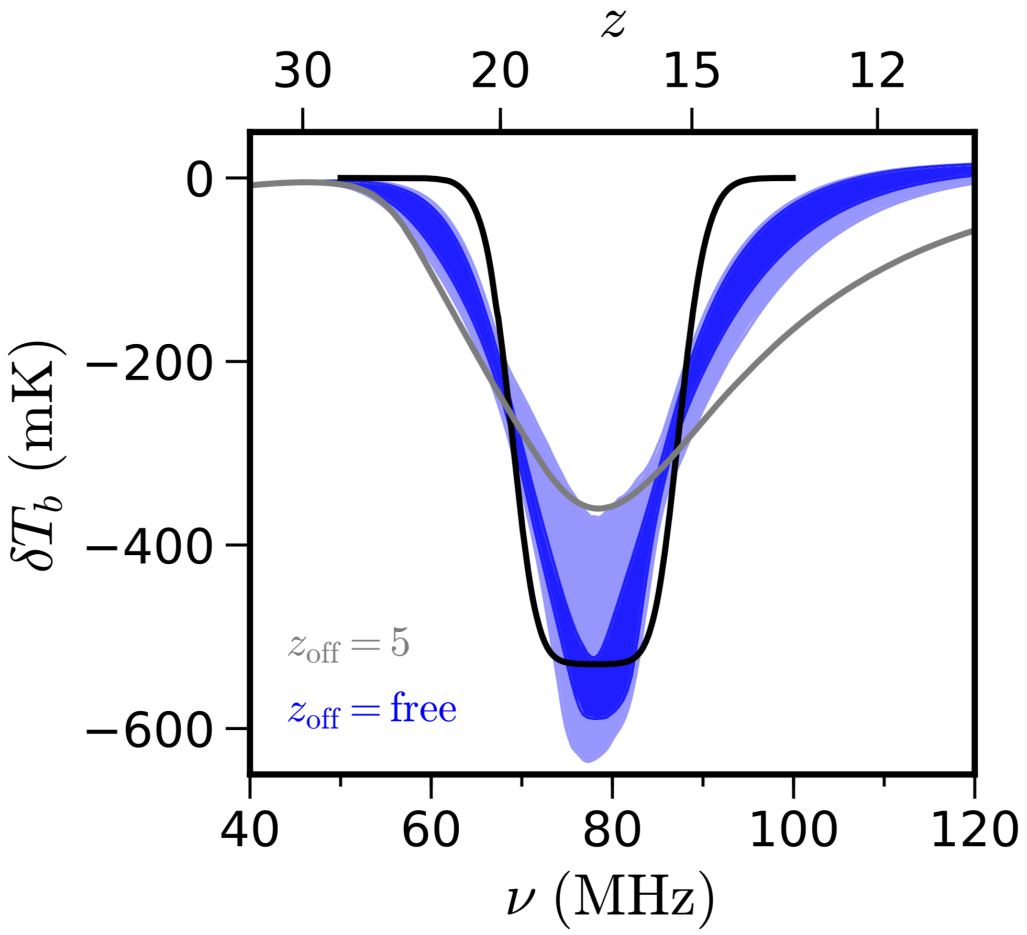
Increase numerator: Excess **radio** background

Decrease denominator: **Cooling** through baryon-DM interaction

1810.05912

A word on data analysis

Most radio/cooling papers use pseudo-likelihood based on B18



which is problematic

Concerns about B18 claim

B18 used a 5-term FG + Flat Gaussian T_{21}

1805.01421 + 1903.04540 + 1910.03165:

B18 is unphysical - implies negative optical depth

Data can be equally well-fit with other T_{21}

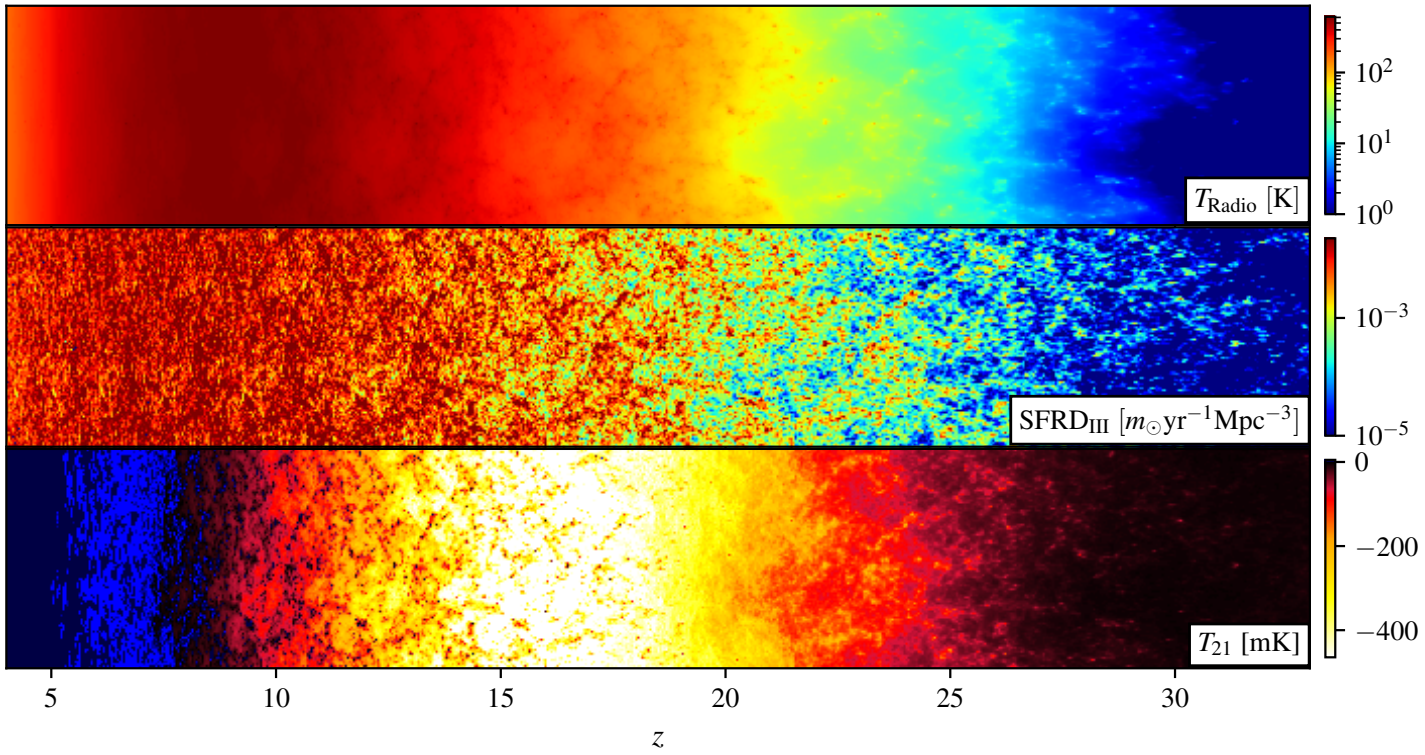
T_{21} can be consistent with LCDM

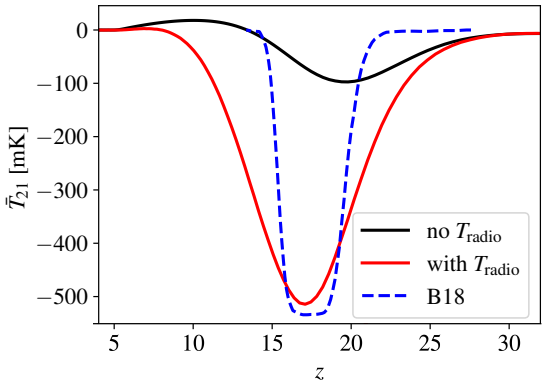
Calibration residuals are present

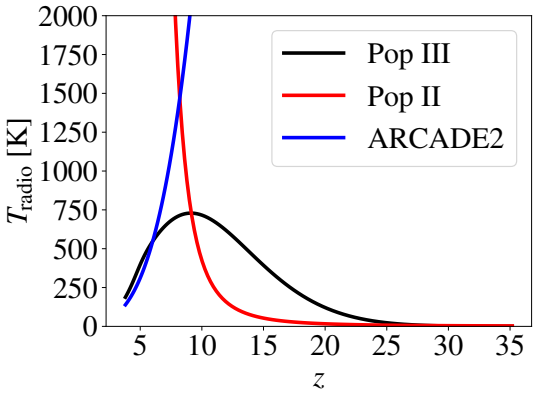
…

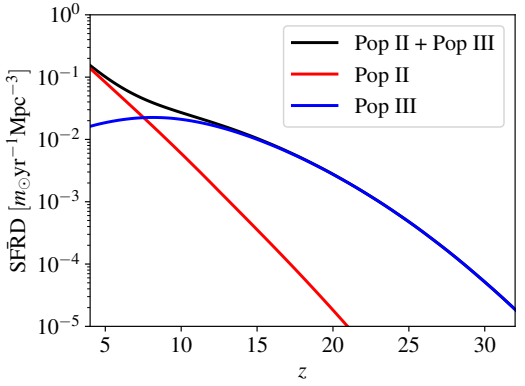
Must use the **likelihood in data space**, NOT pseudo-likelihood based on B18

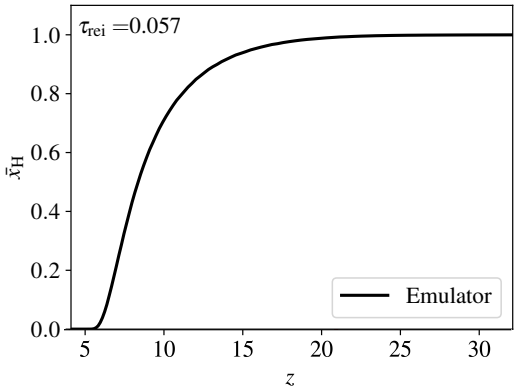
Our model: Pop III radio galaxies











Typical Pop II galaxies violates ARCADE, needs an ad-hoc $z_{\rm off}$

Pop III naturally dies out due to feedbacks, no need for $z_{\rm off}$

https://github.com/Junsong-Cang/21cmFAST/tree/Radio_Excess

Bayesian Analysis

Likelihoods

EDGES (sky temp data):

Cosmic T_{21} + Polynomial Foreground + Calibration Residual

↓ 4-10 terms ↓ `None, Narrow, Broad`

Optical Depth :

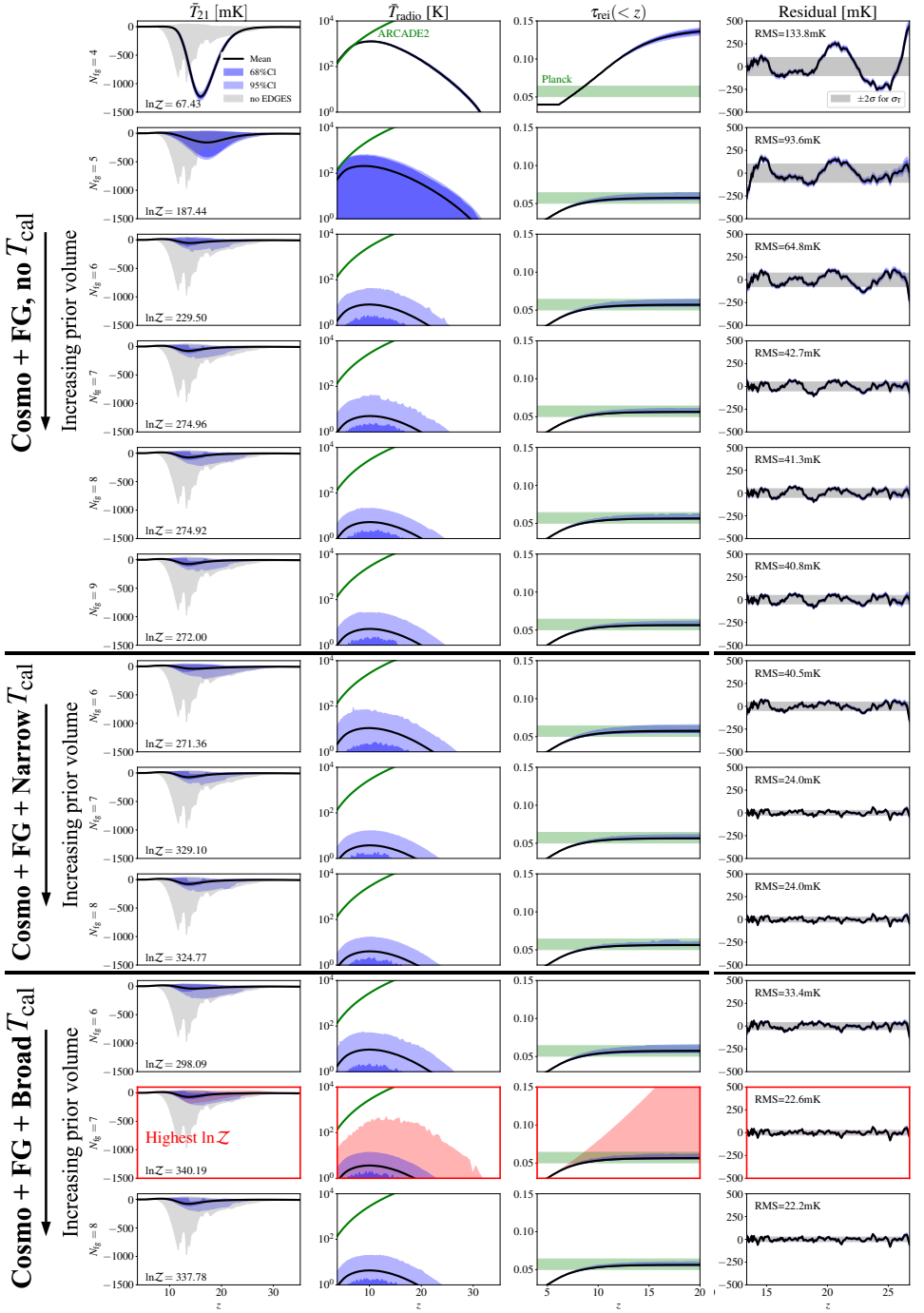
Planck CMB measurements

ARCADE2 :

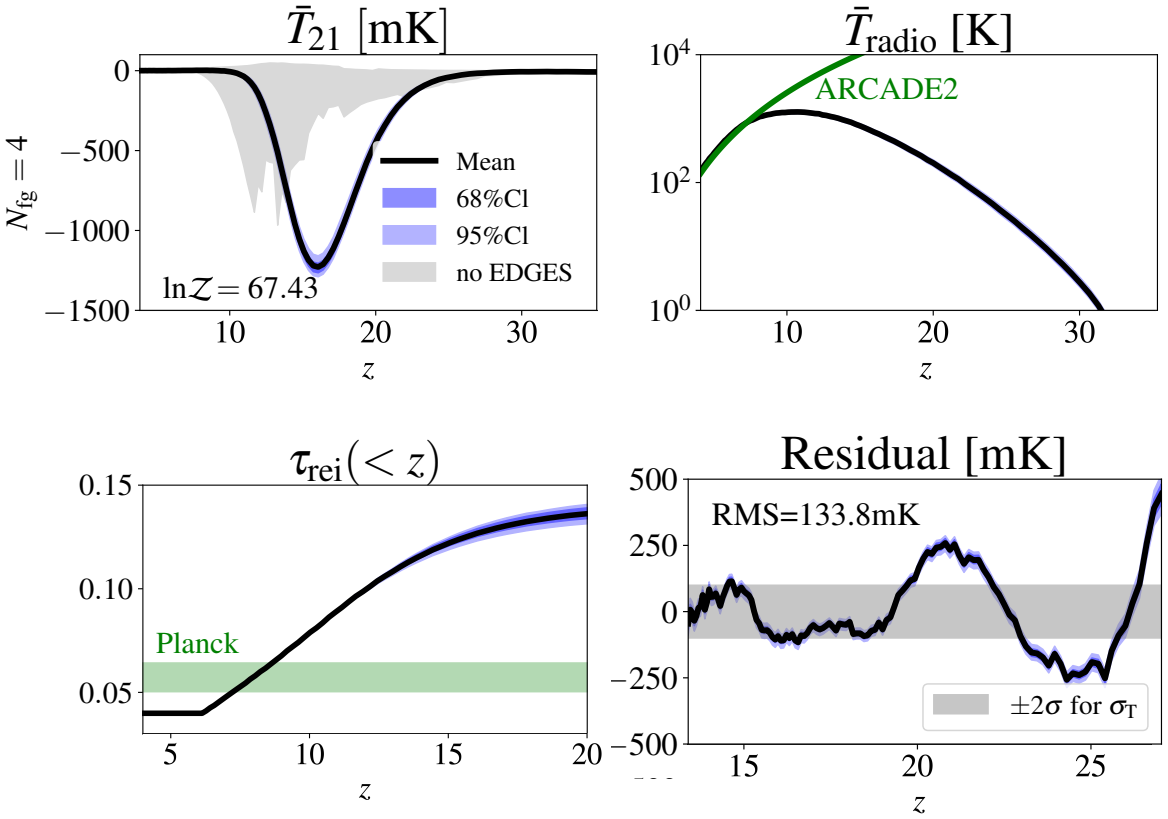
One-sided Gaussian

Bayes Factor

$$\mathcal{Z}(D|\mathcal{M}) = \int \mathrm{d}^{\mathrm{n}}\theta \mathcal{L}(D|\mathcal{M},\theta)\pi(\theta)$$

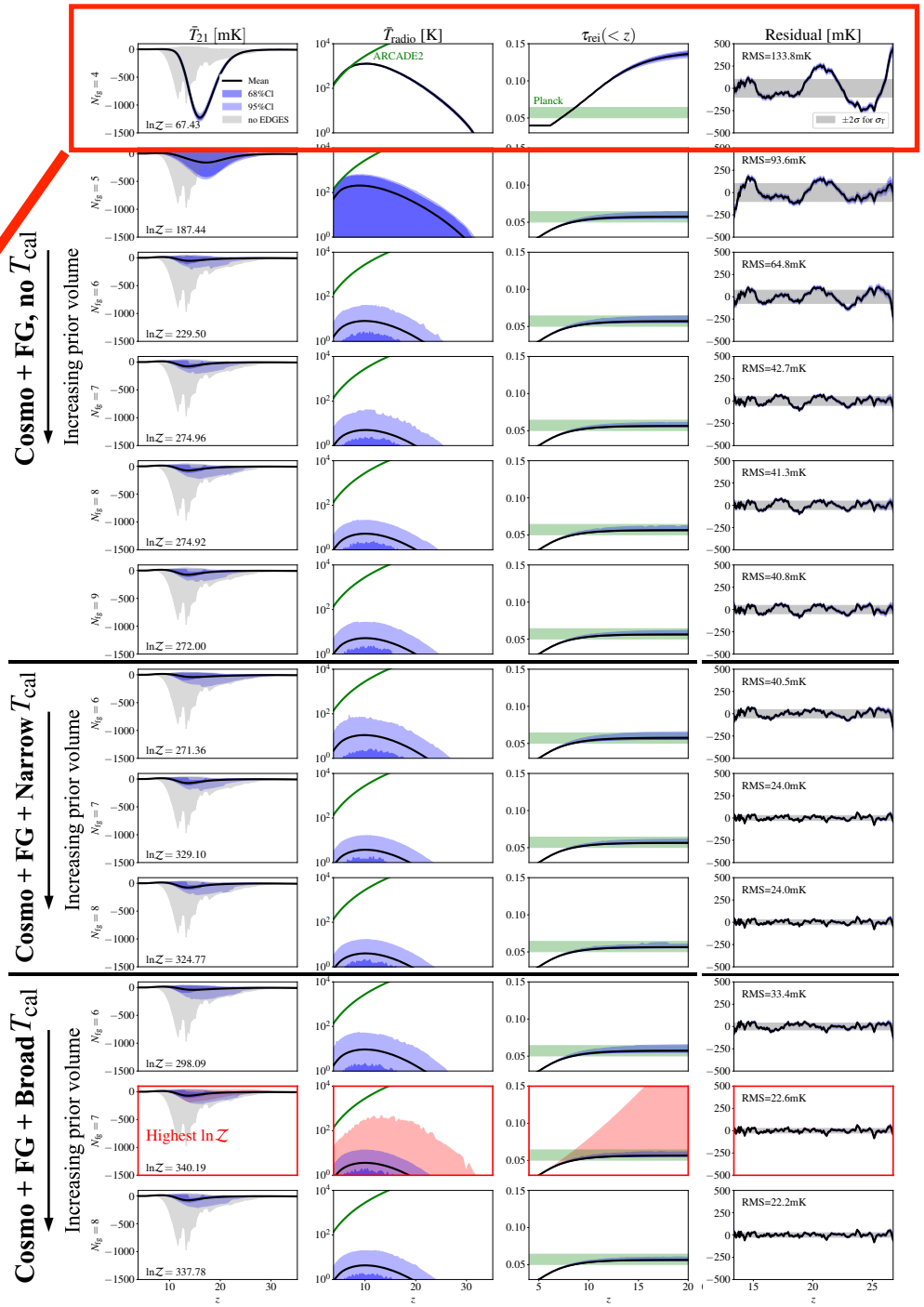


Strong-signal models exist but disfavored



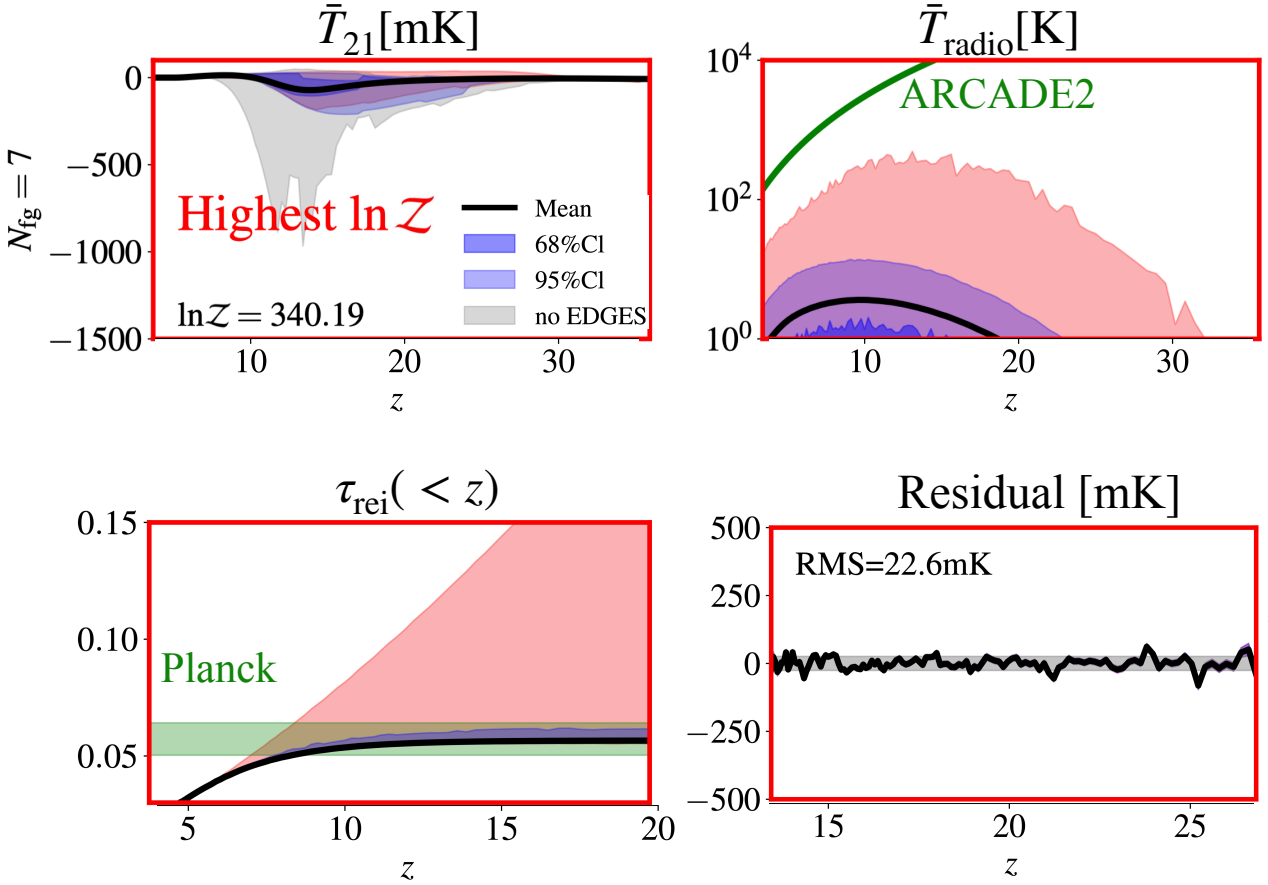
Can get deep signal but …

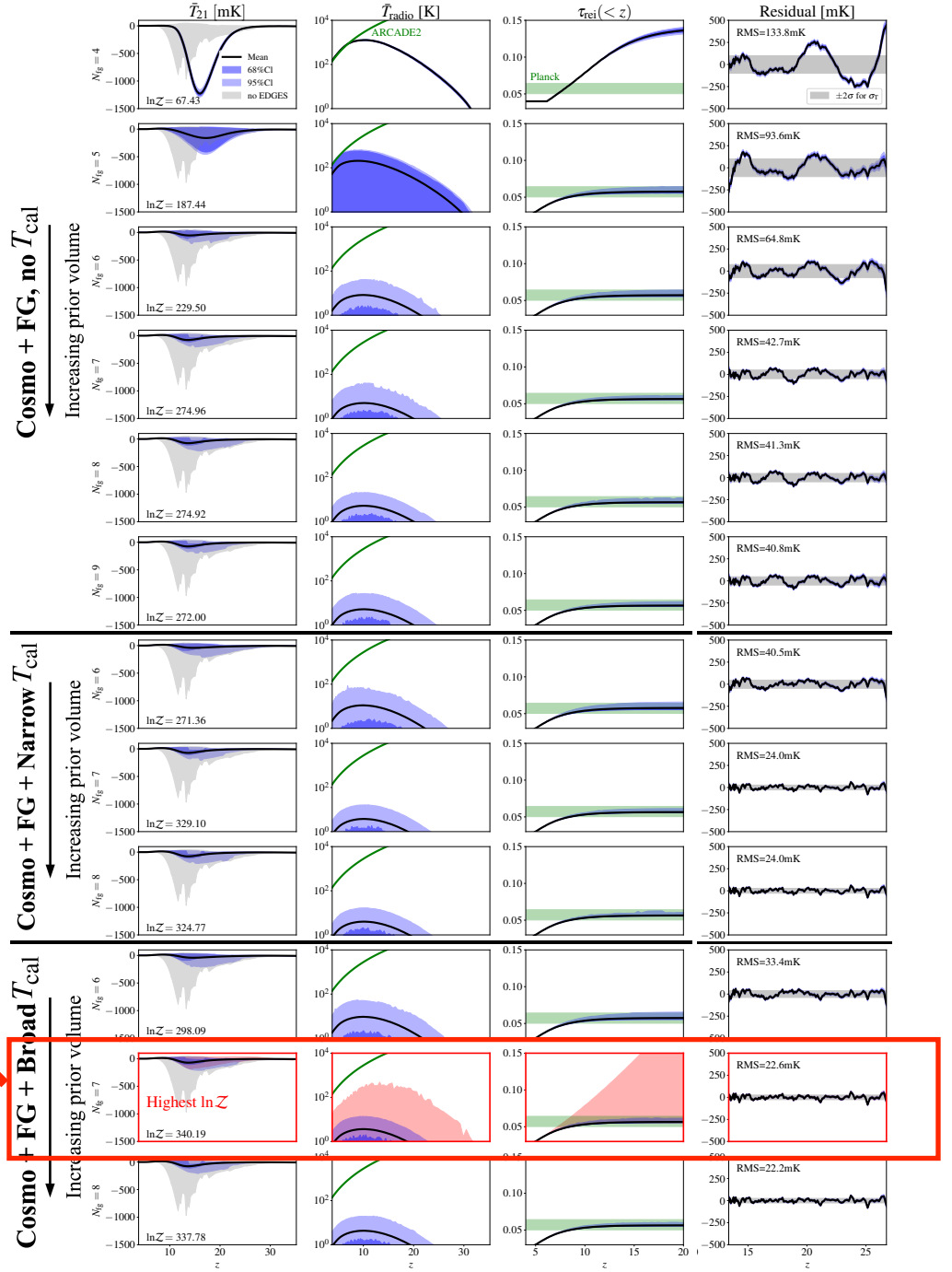
High residuals, high $\tau_{\rm rei}$, low evidence



Maximise the Bayesian evidence

Best-fit model : 7 FG terms, broad $T_{\rm cal}$





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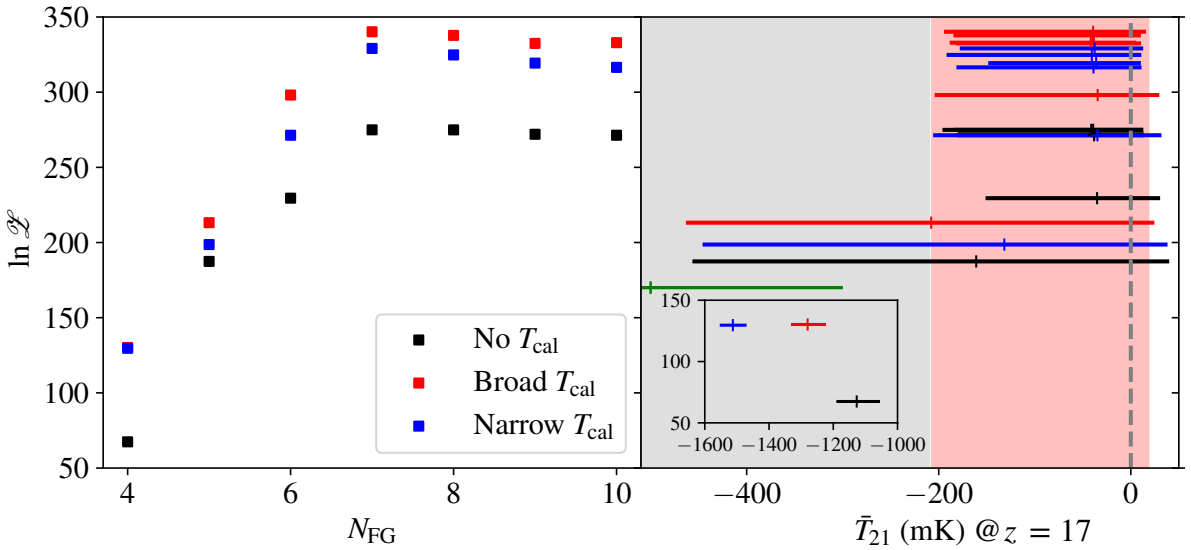
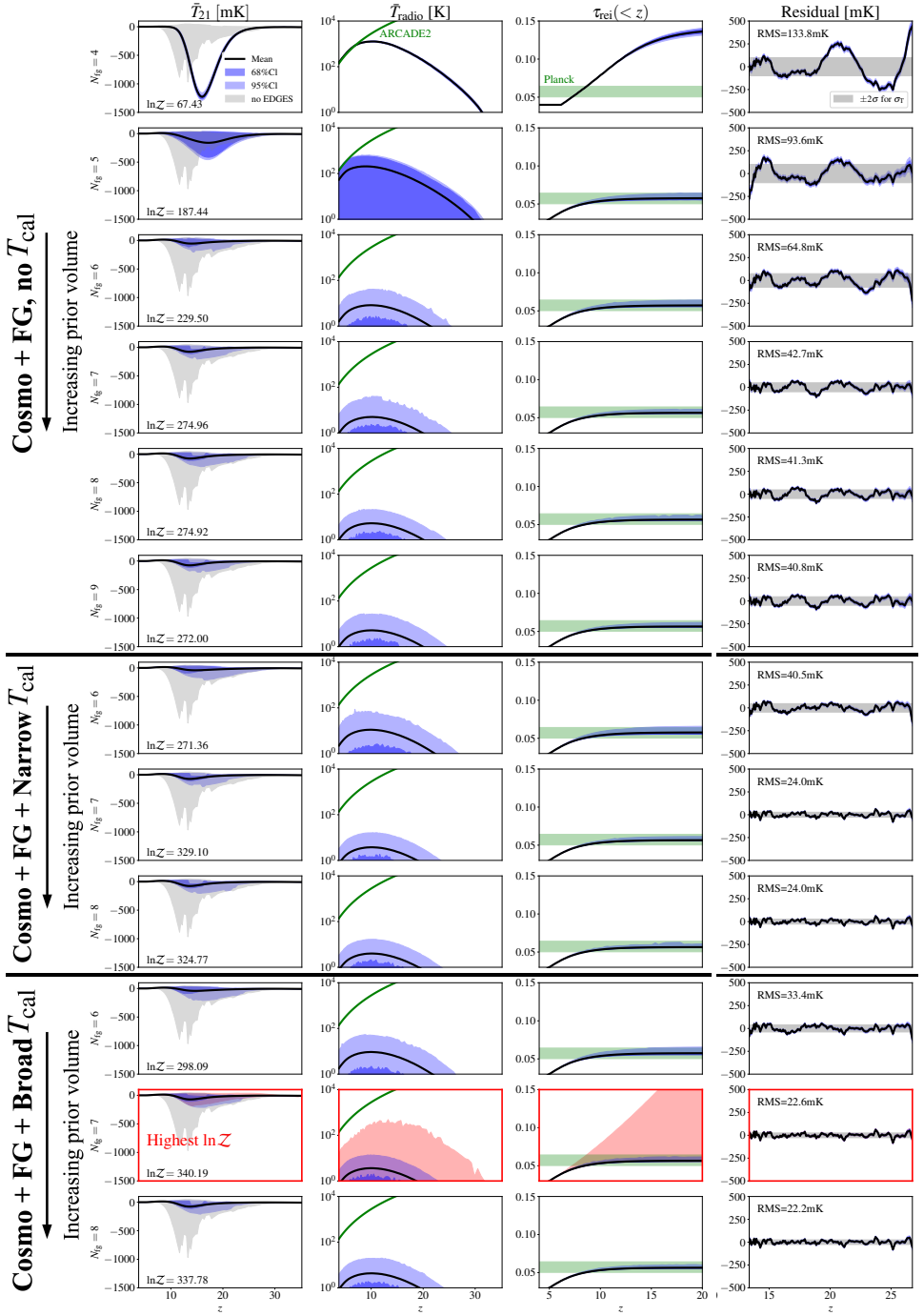


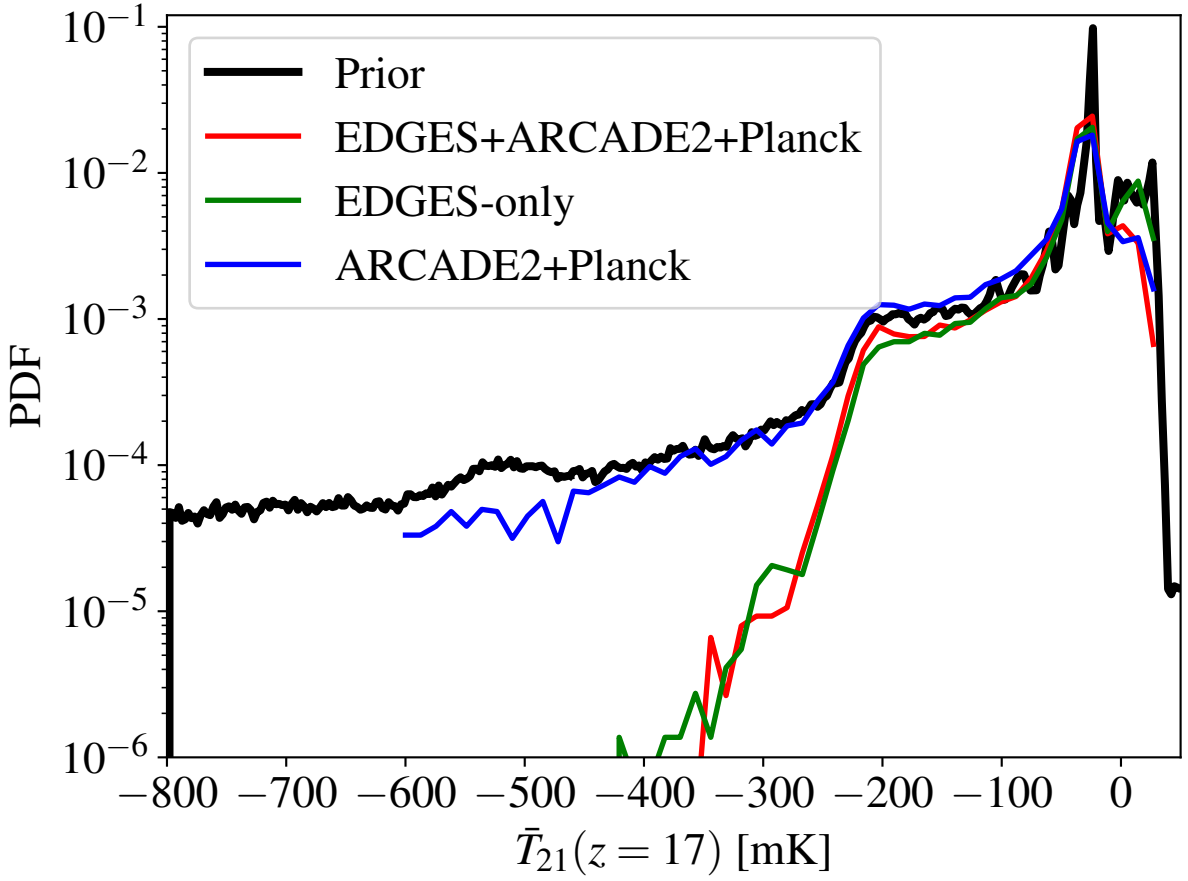
Calibration residual present in EDGES data

Non-ΛCDM depth strongly disfavored

T_{21} posterior dominated by $\tau_{\rm rei}$+ARCADE
- no clear detection from EDGES



EDGES disfavours strong signal



All PDFs are near identical

EDGES only adds very limited information

No clear detection

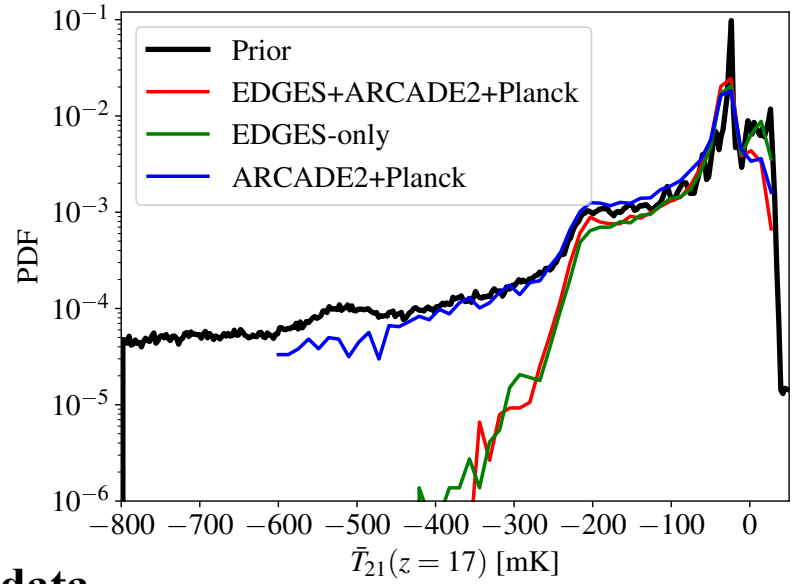
Summaries

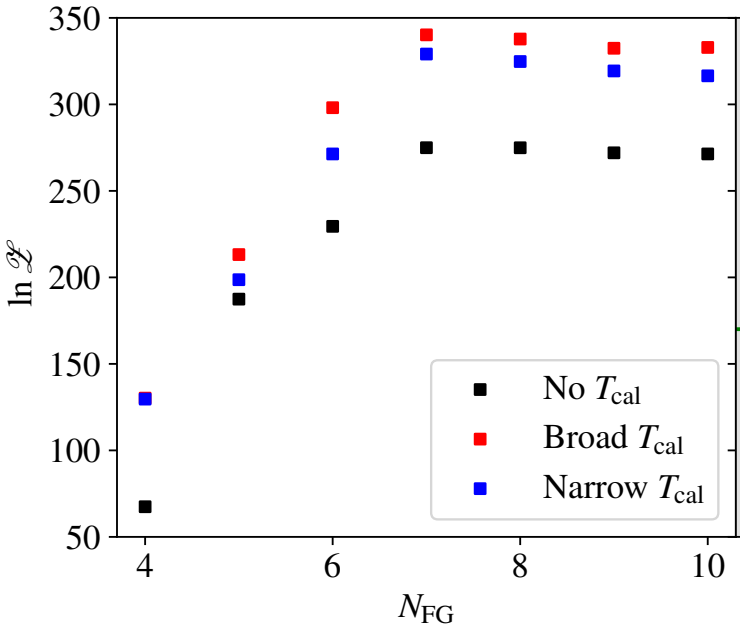
We did Bayesian analysis for EDGES sky temperature data with Pop III radio galaxies

EDGES disfavours non-LCDM depth

EDGES adds little new information

Calibration residual present in EDGES data





Thanks for listening
Comments welcome

JC, AM+, in prep

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Back up

Concerns about B18 claim

B18 used a 5-term FG + Flat Gaussian T21

1805.01421:

B18 Solution is not unique

B18 requires unphysical FG

1903.04540:

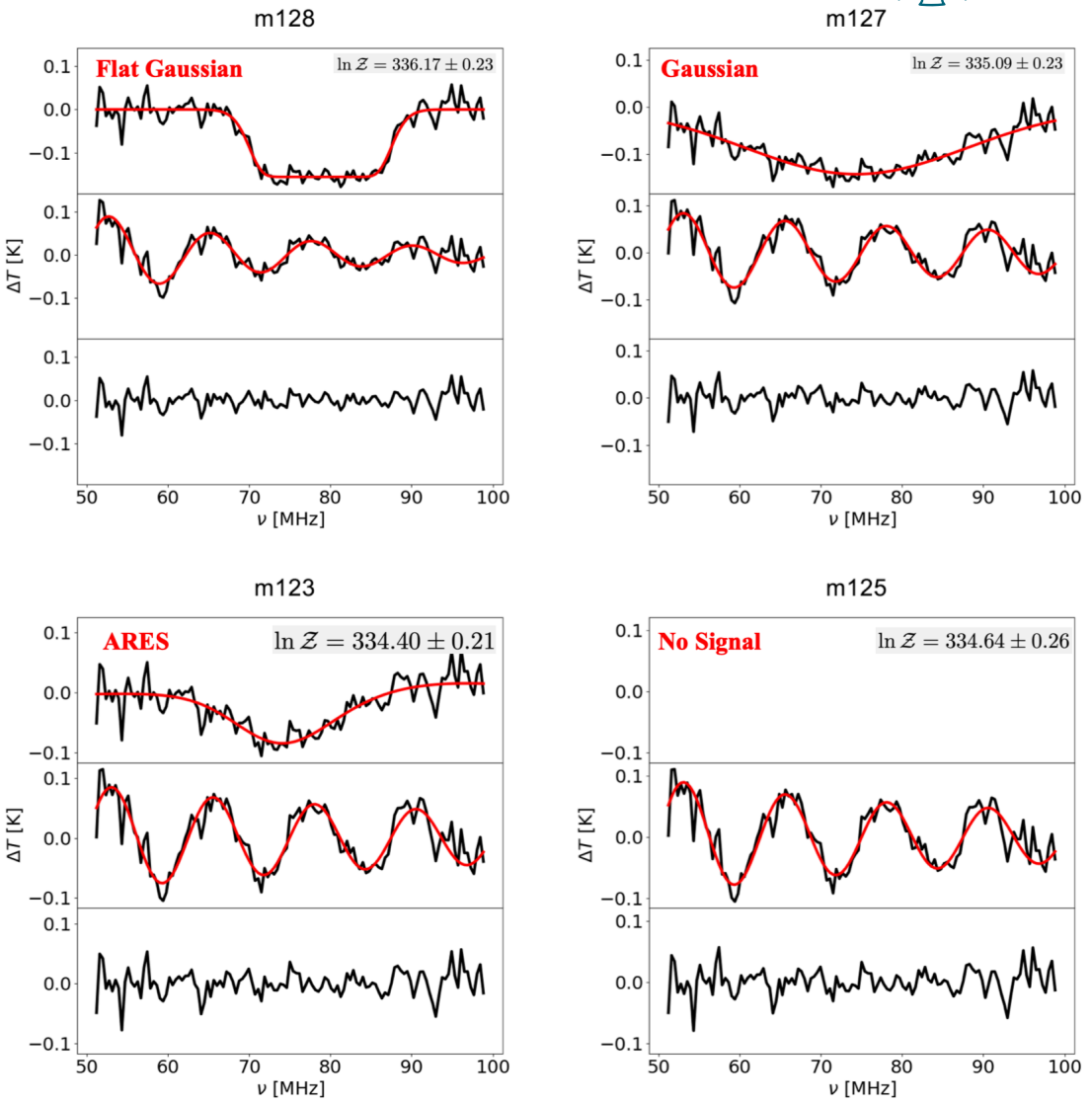
Wave-like residual in EDGES data

1910.03165:

Signal consistent with LCDM

No strong Bayesian preferences for T21 models

Calibration residuals are present



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Likelihoods

EDGES : Cosmic T_{21} + Polynomial Foreground + Calibrations Residual

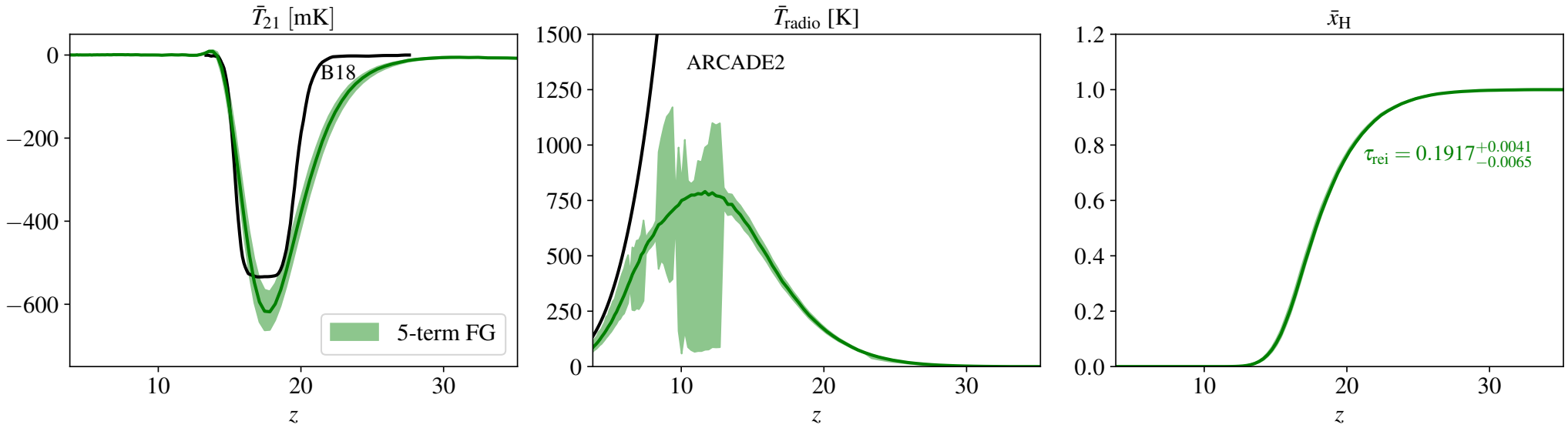
4-10 terms

None, Narrow, Broad

Optical Depth : Planck CMB measurements

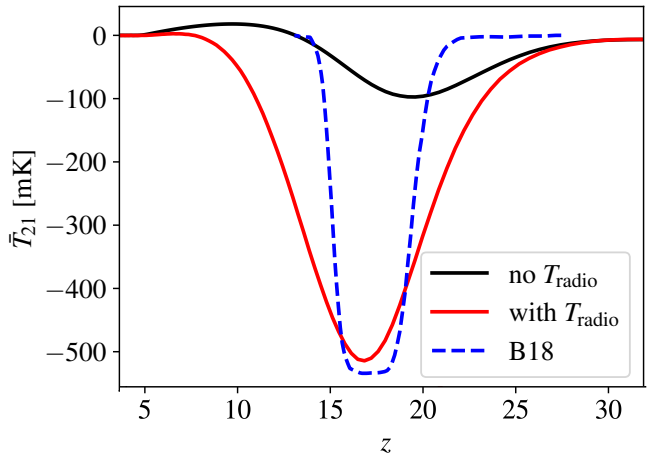
ARCADE2 : One-sided Gaussian

EDGES-only fit prefers high $\tau_{\rm rei}$



A word on data analysis

Most radio/cooling solutions use pseudo-likelihood based on B18



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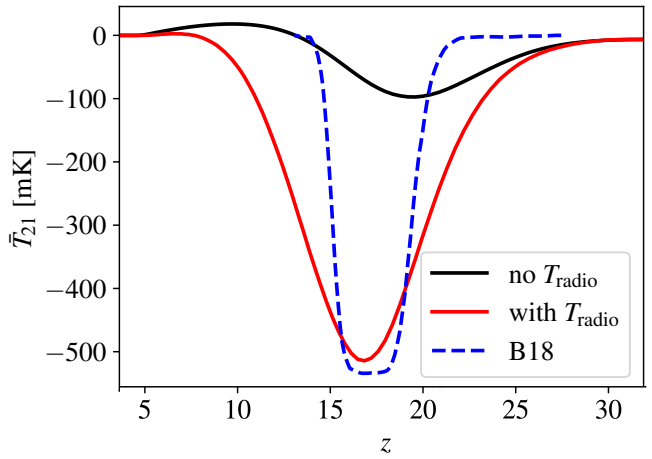

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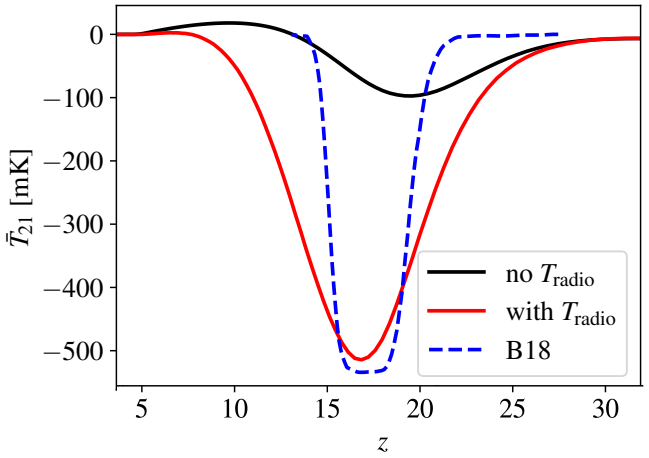

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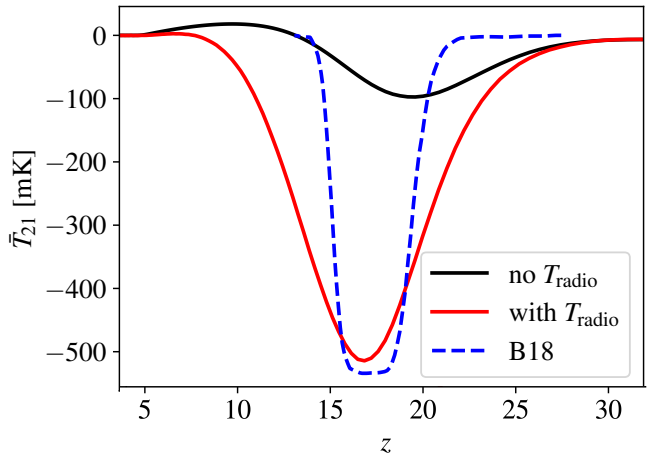

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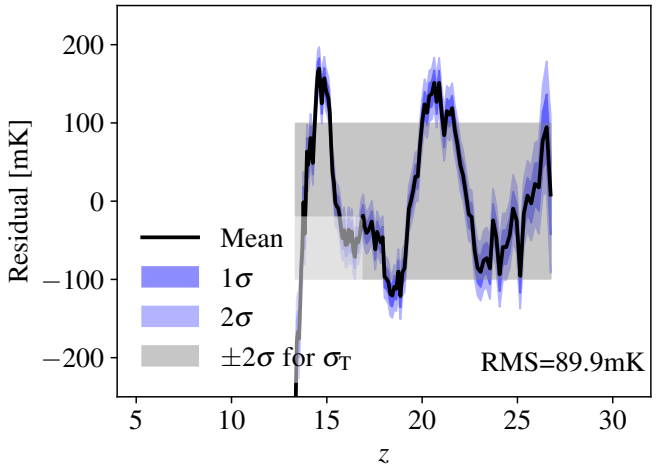

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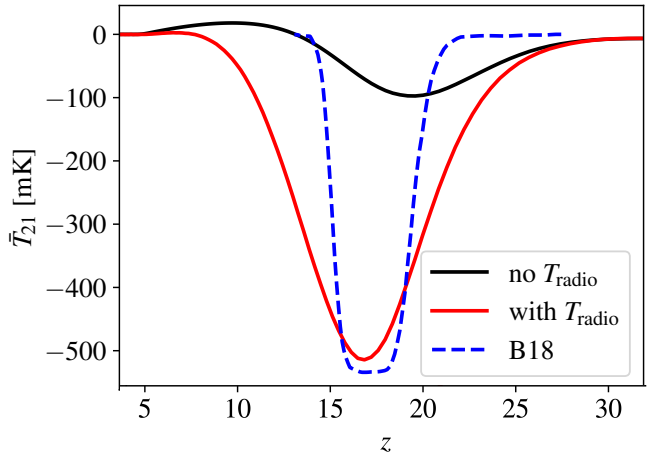

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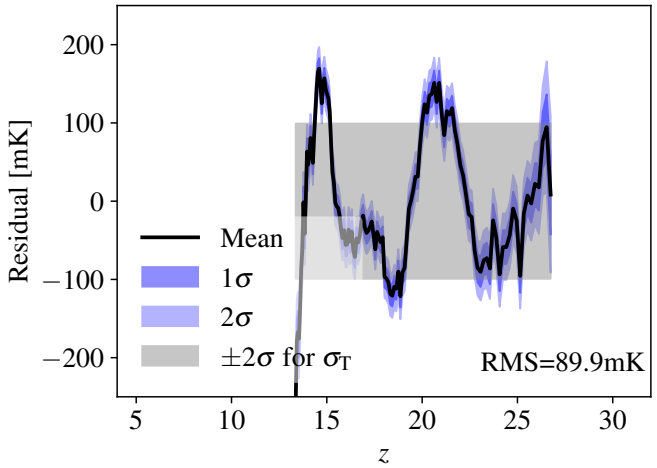

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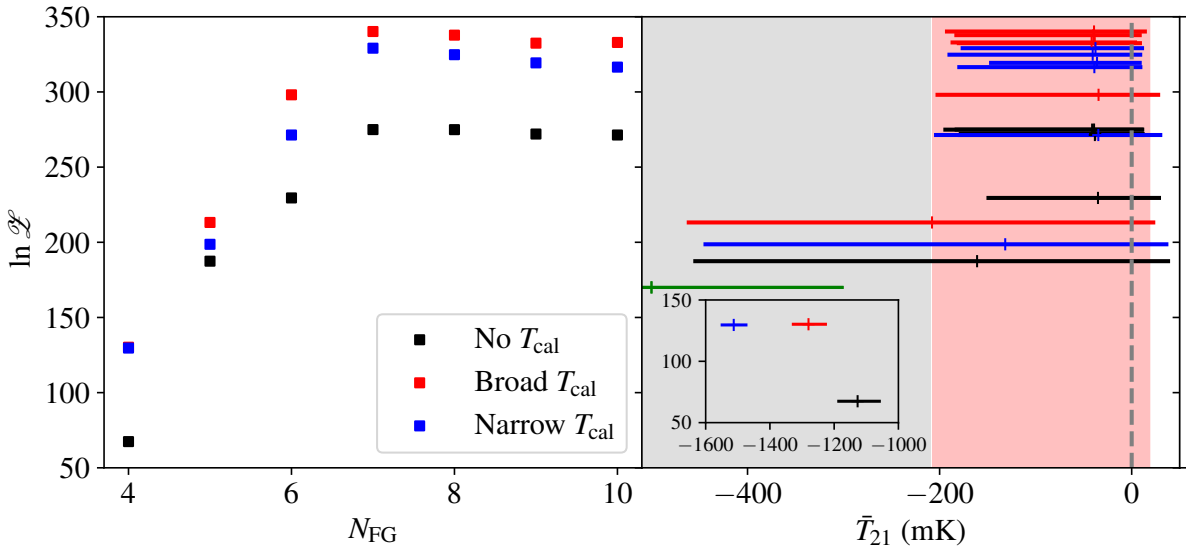

Calibration residual favored

Non-LCDM depth strongly disfavored

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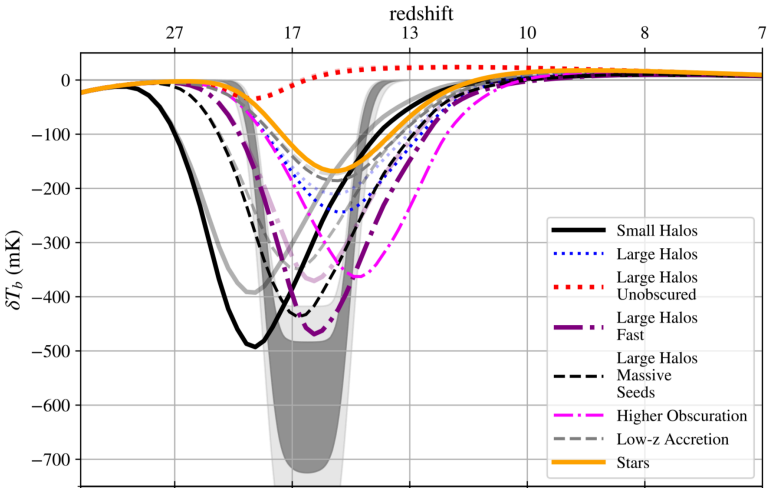

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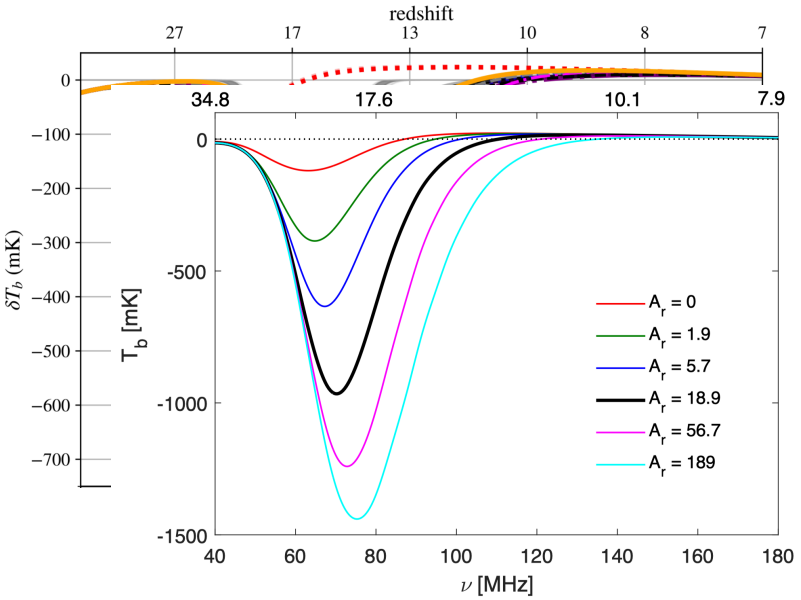

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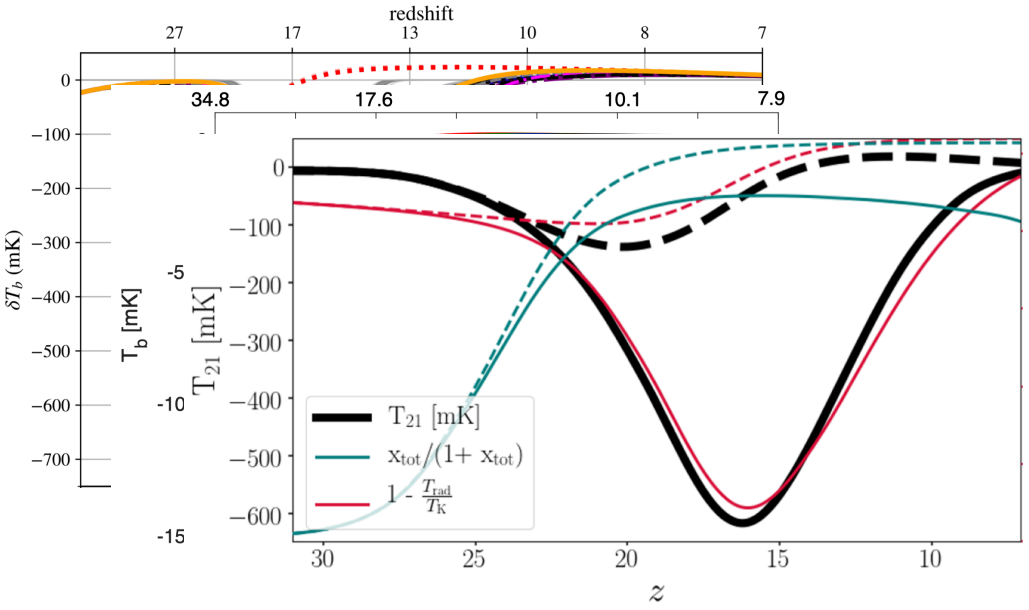

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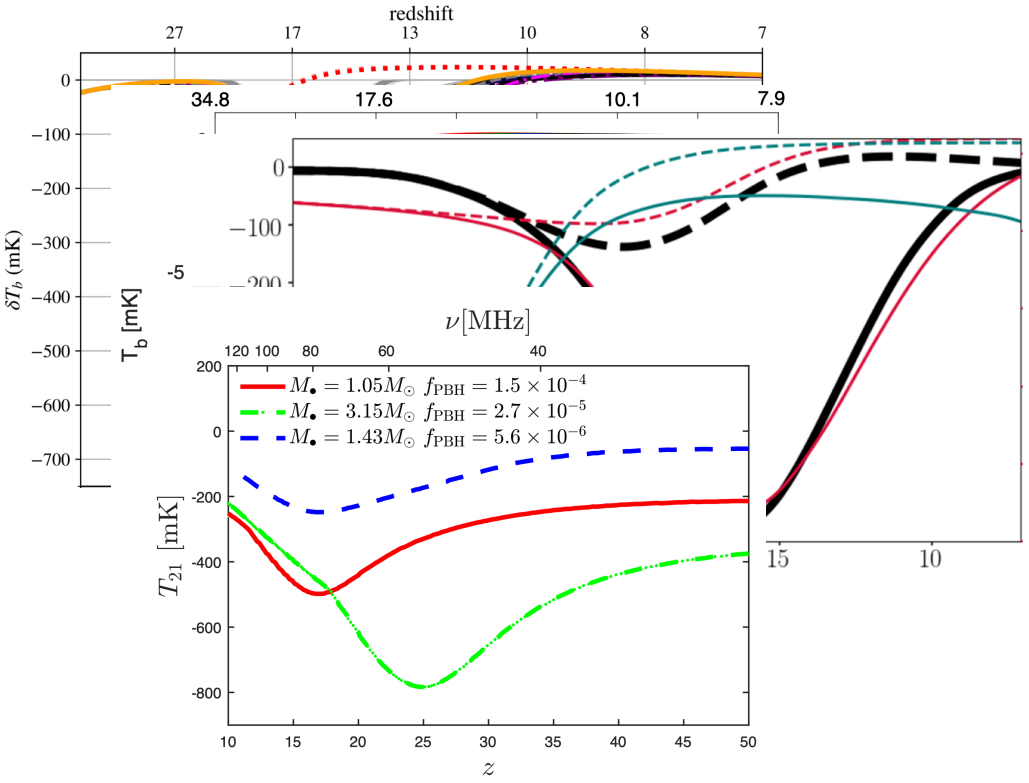

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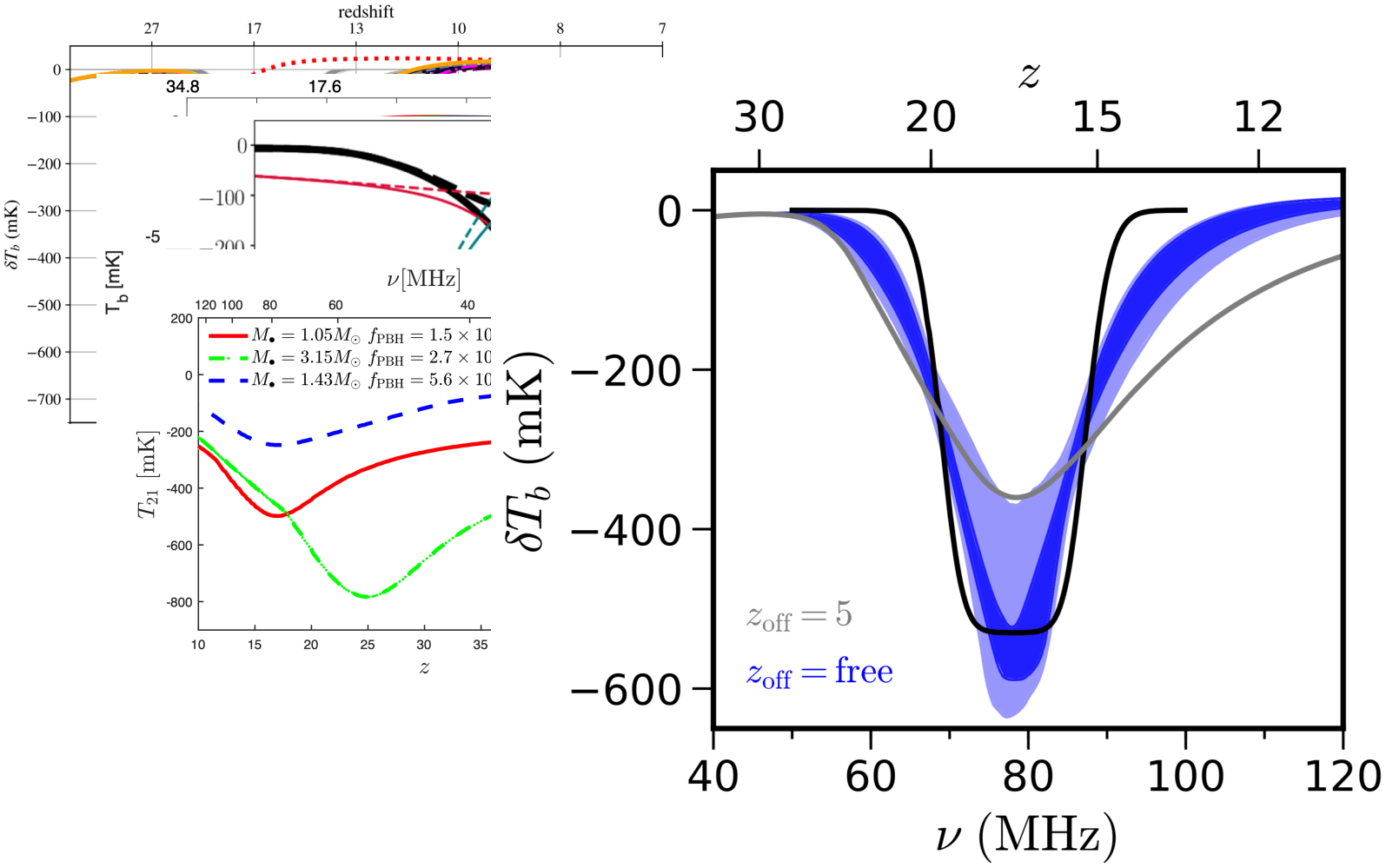

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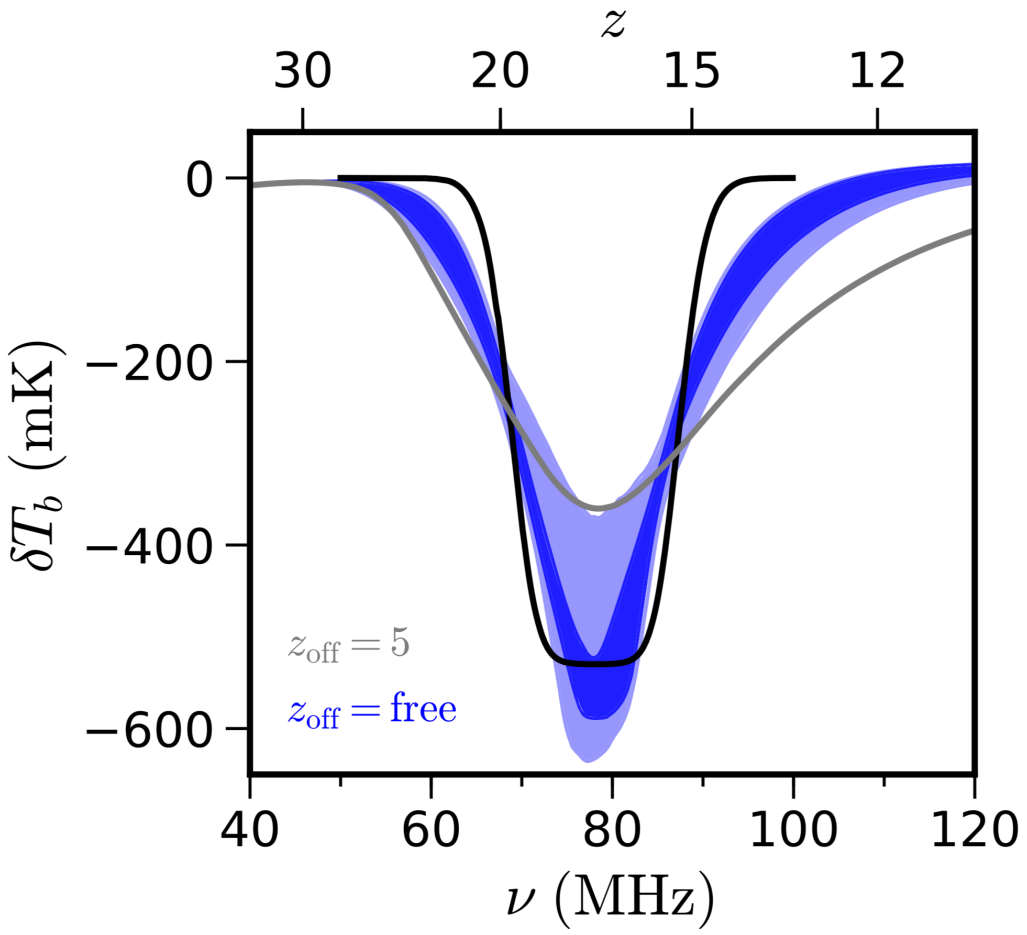

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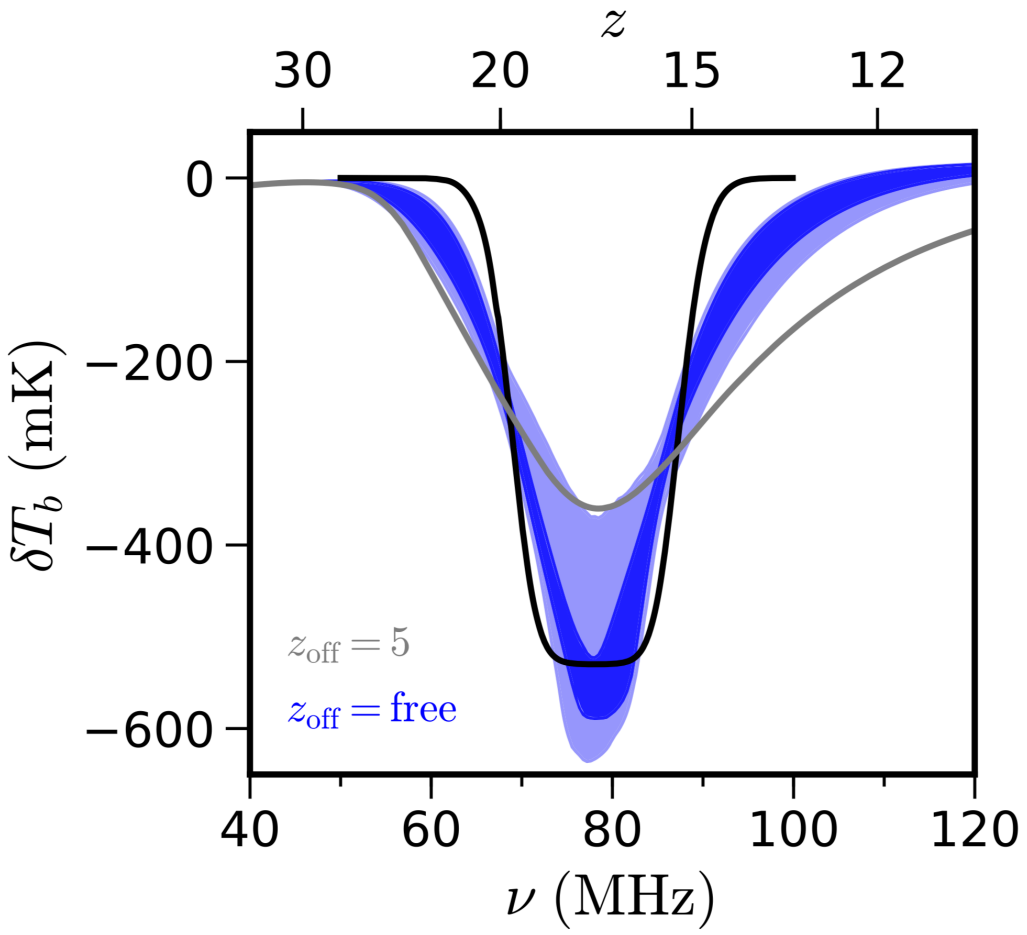

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Bayesian evidence

Likelihood Prior

$$P(\theta|D,\mathcal{M}) = \frac{\mathcal{L}(D|\mathcal{M},\theta)\pi(\theta)}{\mathcal{Z}(D|\mathcal{M})}$$

Posteriors Bayes Factor

$$\mathcal{Z}(D|\mathcal{M}) = \int \mathrm{d}^{\mathrm{n}}\theta\,\mathcal{L}(D|\mathcal{M},\theta)\pi(\theta)$$

$\ln Z(M_1) - \ln Z(M_2) > 3$:

Strong preference for M_1 over M_2